ARSENICAL GAS POISONING.

POISONING

BY

ARSENIURETTED HYDROGEN OR HYDROGEN ARSENIDE

ITS PROPERTIES, SOURCES, RELATIONS TO SCIENTIFIC AND INDUSTRIAL OPERATIONS, SYMPTOMS, POST-MORTEM APPEARANCES, TREATMENT, & PREVENTION:

WITH A RECORD OF ONE HUNDRED AND TWENTY CASES BY DIFFERENT OBSERVERS

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PREFACE.

THE following pages are the outcome of an investigation into the literature of poisoning by Arseniuretted Hydrogen consequent upon two cases which came within the experience of the writer.

Notwithstanding the extremely poisonous character of this gas, it is surprising what little attention, comparatively speaking, has hitherto been paid to it in books devoted to Forensic Medicine and Toxicology, or, indeed, in the literature of medicine generally. From the occurrence of its toxic effects among persons engaged in very varied scientific and industrial pursuits, perhaps too little heed has been given to its incidence from the point of view of prevention.

Up till now, so far as we are aware, there has not been any systematic treatment of the subject, if we except a monograph by Geigy which deals with the record of thirty-seven cases, that of Lucas, with only a few, and some of these already recorded by Geigy, an article in one of our English medical periodicals by Dixon Mann and Clegg, which adds twelve additional cases, and some articles relative to the toxic results upon persons especially connected with military ballooning.

The remaining recorded cases which find a place in these

pages have been found as isolated contributions in the columns of home and foreign medical journals, or as the bases of inaugural theses of graduates for the doctorate degree of Continental universities. They number in all one hundred and twenty cases.

The writer, therefore, has tried in this little book to bring together in collected form all recorded cases from all sources known to him, as well as to consider the original records of the earlier cases, some of which are almost invariably quoted by previous writers. It is quite probable, however, that some cases have been overlooked, because the field of medical literature is now so very wide; at the same time, an honest endeavour has been made to include in his pages all the known published cases, as well as some that have hitherto not been recorded.

From the very widespread use of arseniferous chemicals, notably of hydrochloric and sulphuric acids and metals, in many departments of chemistry in laboratories and chemical works and other industrial pursuits, it is obvious that cases of fatal poisoning are likely to arise in the future from time to time, and, sometimes, even under circumstances in which their occurrence might not be anticipated.

If these pages serve no other purpose than to warn still more urgently against the possible risks of using such substances, or to cause precautions of an adequate kind to be taken in the known use of such substances, the book will have fulfilled its intention.

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CHAPTER I.

PROPERTIES AND SOURCES OF ARSENIURETTED HYDROGEN.

ARSENIURETTED hydrogen, arsenetted hydrogen, arsine, tri-hydride of arsenic, arseniate of hydrogen, hydride of arsenic, and hydrogen arsenide are several of the names by which the gaseous compound of arsenic and hydrogen is designated. There is, however, another compound of these two elements. It exists in the solid state, and is commonly known as the hydride of arsenic, having the chemical formula of AsH_2 or As_2H_4. The gaseous form, on the other hand, has the formula of AsH_3, and may be produced in a variety of ways, the essential factor in its production being the presence of nascent hydrogen in arseniferous solutions. This gas, therefore, has the same chemical constitution as ammonia, NH_3, except that the arsenic takes the place of the nitrogen. While we have but a passing interest in the solid hydride, it will probably be more convenient to dismiss it from further consideration by saying now what needs be said concerning it. In testing for arsenic under certain circumstances, the solid hydride may be formed, and error in the quantitative estimation of the total arsenic present may thereby result;

for example, in employing Marsh's process it is of the utmost importance that nitric acid, even in the smallest amount, should not be present, else the formation of the gaseous hydride will be prevented to some extent at least, and, instead, the solid hydride will be apt to be deposited as brown-coloured flakes upon the zinc used in the generation of the hydrogen. Again, if the gaseous hydride be passed through strong sulphuric acid (sp. gr. 1,260 to 1,843), the acid first changes into a brown colour, and, if the flow of gas be further continued, a brown flocculent precipitate is thrown down, which, being partly converted into arsenious sulphide, results in the evolution of some hydrogen sulphide gas. After the experiment has been continued for an hour, analysis of the collected precipitate shows that its composition is as follows:—

Arsenic	95 per cent.
Sulphur	4·6 per cent.
Hydrogen . . .	0·29 to 0·32 per cent.

From which it would appear that the precipitate is composed of a mixture of the solid arsenic hydride, metallic arsenic, and arsenious sulphide.

Moreover, in contact with air, chlorine, nitric acid, and other gases, the gaseous hydride is decomposed into metallic arsenic and the solid hydride.

Since our interest at present, however, is centred upon the gaseous form, it will be well that we should consider some of the ways by which it may be produced, in view of the consideration which is proposed to be given in subsequent pages to cases of poisoning due to its entrance into the human body under diverse circumstances.

The following are some of the principal, viz.:—

1. By the solution of arsenides of the metals in water, the solid hydride being formed at the same time.

2. By acting upon alloys of zinc, tin, or arsenic, or ores containing these or other metals and arsenic, or upon arseniferous zinc, with hydrochloric acid or sulphuric acid.

3. By the generation of hydrogen from zinc and impure hydrochloric or sulphuric acid, either or both of which contain some proportion of arsenic.

4. By Marsh's process, so-called from Mr. Marsh of Woolwich, who in 1836 was the first to employ the gas test for arsenic.

5. By dissolving zinc, tin, or iron in a solution of arsenic acid, with a dilute acid.

6. By electrolysis of arsenious or arsenic acid in solution in water.

Arsenious oxide, or arsenious acid as it is commonly called, has the formula As_2O_3, or As_4H_6, and each molecule of the solid oxide unites with three molecules of water to form two molecules of arsenious acid, thus :—

$$3H_2O + As_2O_3 = 2H_3AsO_3.$$

This arsenious acid, a tribasic acid, has a feebly acid reaction, but up till now has not been obtained in the free condition.

The chemical reactions which happen in Marsh's process, or in the electrolytic process, and generally when arseniferous metals or alloys are mixed with an acid, are as follow :—

$$3Zn + 3H_2SO_4 + H_3AsO_3 = 3ZnSO_4 + 3H_2O + AsH_3$$
$$3Zn + 6HCl + H_3AsO_3 = 3ZnCl_2 + 3H_2O + AsH_3$$

or :

$$As_2Zn_3 + 6HCl = 2AsH_3 + 3ZnCl_2$$
$$As_2Zn_3 + 3H_2SO_4 = 2AsH_3 + 3ZnSO_4.$$

With arsenic acid the equations are as follow :—

$$4Zn + 4H_2SO_4 + H_3AsO_4 = 4ZnSO_4 + 4H_2O + AsH_3$$
$$4Zn + 8HCl + H_3AsO_4 = 4ZnCl_2 + 4H_2O + AsH_3.$$

The gas which is obtained from any of the foregoing reactions is not pure, but is always mixed with more or less hydrogen. It may be collected over water, but the most scrupulous care must be exercised in any dealings with the gas because of its extremely poisonous action. It is a colourless gas, and possesses a disagreeable odour, which has been described as "extremely repulsive," but which may be equally well, and more intelligently described as alliaceous or garlicky. It does not redden litmus. Its specific gravity according to Dumas is 2·695, air being reckoned as 1. One volume of the gas contains one and a half volumes of hydrogen and one-quarter volume of vapour of arsenic. It contains 96·15 per cent of arsenic. One cubic centimetre of the gas at a pressure of 760 millimetres and 0° C. contains as much metallic arsenic as is equivalent to 0·0044 gramme of arsenious acid. Two cubic inches of the gas contain 1½ grains of arsenic, as arsenicum. It liquefies at − 40° C. according to Stromeyer, but does not solidify even at − 110° C. It is slightly soluble in water, does not combine with acids or bases, and decomposes solutions of many of the metals which are precipitated by sulphuric acid, its hydrogen alone being oxidised and the arsenic precipitated in combination with the metal. At a red heat it is decomposed into free hydrogen and metallic arsenic. It burns in the air with a bluish-white flame, forming water and arsenious acid, which is deposited as a white crust or precipitate upon porcelain held just above the flame. If, however, the porcelain be held in the middle of the flame, the deposit will largely, if not entirely, consist of metallic arsenic.

There is another mode by which this gas, or a kindred gaseous form of arsenic, is evolved, and that is by the

growth of certain moulds in substances containing arsenious acids or arsenites, or even arsenic acid and arseniates. It is now well established that during the growth and development of such moulds hydrogen is evolved, and that if this evolution takes place in an arseniferous material a gaseous compound of hydrogen and arsenic is produced. This is a matter of considerable importance relative to arsenical wall-papers which are hung by the agency of paste made with flour or starch and water, because the flour or starch is an agreeable medium for such mould growth, and because of attacks of arsenical poisoning which have arisen, and are apt to arise, in persons living in rooms so decorated. To this we shall allude in more detail later.

By reason of the fact that zinc and other metals and commercial hydrochloric and sulphuric acids are more or less contaminated with arsenical impurities it becomes a matter of urgency that due precautions should be taken whenever operations involving the use of these, or some of them, in combination are engaged in, and it is for this reason that it becomes absolutely essential, whenever it is necessary to employ Marsh's process, where zinc and sulphuric or hydrochloric acid are used, for the detection of arsenic, that the reagents should be arsenic-free and should be proved to be so.

Otto[1] emphasises the constancy of the impurity of arsenic in hydrochloric acid; indeed, he goes the length of saying that "the purity of the hydrochloric acid which, in the process for the detection of arsenic and the metals in general, is often used in considerable quantities, should more especially be attended to. The acid should be treated with sulphuretted hydrogen, for there is no other

[1] *On the Detection of Poisons*, 1857, p. 10.

way to remove those traces of arsenic which are, perhaps, never wanting, but which become only evident in operating in large quantities. Four pounds of crude hydrochloric acid which I use in my laboratory for the preparation of the pure acid, and which passes generally for being free from arsenic, afforded, on being diluted with an equal volume of water and treated with sulphuretted hydrogen, a deposit in which the presence of the arsenic could be distinctly shown by Marsh's test."

This is further corroborated by the casual examination of almost any sample of the crude acid of commerce, and, moreover, of samples which make greater claims for purity. If we examine the figures given by Lunge,[1] the above statement will be amply verified. The following table will indicate how variable are the proportions of arsenic which are found.

TABLE I.

Name of Observer.	Amount of Arsenic found.	Per cent of As_2O_3.
Houzeau . . .	0·1 gram $AsCl_3$ per kilo.	0·0055
Filhol and Lacassin .	1·02 to 5·007 ,, ,,	0·102 to 0·5007
Glenard . . .	2·5 grams ,, ,,	0·25
H. A. Smith . . .	6·91 ,, ,, ,,	0·691
In pan acid 36° T. .	0·66 gram ,, ,,	0·066
Hjelt—In roaster acid, 32° T.	0·014 ,, ,, ,,	0·0014

The same is true likewise respecting the impurity of sulphuric acid. Commercial acid being now so largely made by roasting iron pyrites or mixed iron and copper pyrites, both of which contain relatively high proportions of arsenic, it is not difficult to recognise the source of the arsenic. In the sulphuric acid used at Waltham Abbey

[1] *Sulphuric Acid and Alkali*, vol. ii. p. 180.

for the purpose of generating hydrogen for lead-burning, the amount of arsenic, as arsenicum, was found to vary from 0·00011 per cent to 0·00022 per cent.[1] And since hydrochloric acid is not infrequently made from common salt acted upon by this impure acid, the reason for the impurity of the hydrochloric acid will also become apparent.

The amount of arsenic contained in sulphuric acid is sometimes not small. In 1856 Cameron stated in the *Chemical Gazette* that he found that about an ounce of crystallised arsenious acid was deposited after long standing from eight pounds of this acid. Since that time, however, the comparative purity of sulphuric acid has improved, and it is now possible to purchase acid guaranteed free from arsenic, which is manufactured from sublimed sulphur. At the same time, most ordinary acids of commerce are still arseniferous, and as it is from this class of acid that accidental poisonings are most apt to occur, it is essential, in order to avoid risks especially where hydrogen is likely to be evolved, that preliminary trials of purity should be made. It ought to be remembered that even at the present time some acids may be found to contain arsenic in amounts as high as from 0·045 to 0·140 per cent.

The dire results of this contamination or impurity have been brought home to the public by the arseniferous acid used in the manufacture of glucose, which, in turn, was employed in the brewing of beer, from which, in Manchester especially, and in other parts of England, thousands of cases of arsenical poisoning arose, the most prominent symptom of which probably was peripheral neuritis.

[1] Report by Dr. Robertson, 1904.

In like manner zinc is very frequently contaminated with the same impurity. This is especially true of commercial zinc. Otto has compiled the results of analysis of different zincs by different chemists. He states that Jacquelin could not detect any arsenic in French products, that Brett[1] could not find in any British or foreign zinc any arsenic by a process capable of detecting 1-5000th part of that substance, but that Schäuffele[2] found, on the other hand, the following quantities of arsenic per kilo. of different zincs.

The amount of arsenic, as arsenicum, found in samples of spelter used at Waltham Abbey varied from 0·00004 per cent to 0·008 per cent.[3]

TABLE II.

	Arsenic in terms of a gram.	
	Villain's Method.	Jacquelin's Method.
French zinc . . .	0·00426	0·019
Silesian zinc . . .	0·00097	0·00853
Vielle-Montagne zinc .	0·00062	0·0045
Corfall zinc . . .	0·00005	...

From a general survey of the cases recorded, of which a more or less full account is given in succeeding pages, it will be seen that most of the accidental poisonings had their origin in the use of these or some of these arseniferous acids and metals.

[1] *London Philosophical Journal*, 1842.
[2] *Journ. de Chimie médicale*, 3rd series, t. vi.
[3] Dr. Robertson, Report, 1904.

CHAPTER II.

RELATION OF POISONING BY HYDROGEN ARSENIDE TO SCIENTIFIC AND INDUSTRIAL OPERATIONS.

In a succeeding table (V., App.), wherein an attempt has been made to associate with each case of poisoning the source of the gas and the occasion upon which it was generated, the range of risk of poisoning by this gas to industrial and other pursuits will be readily perceived.

Obviously, the hydrogen arsenide was liberated in every case in which nascent hydrogen was being evolved in the presence of arseniferous materials. The occasion for such a chemical reaction as the generation of hydrogen arises in many pursuits; for example, in physical and chemical experiments, in industrial occupations as far apart as researches in colours from anilin derivatives, the making of toy balloons, the filling of military balloons, the synthetic manufacture of chemical substances, the making of bleaching-powder, and the solution of arseniferous metals with hydrochloric and sulphuric acids, or of pure metals with arseniferous acids, such as the manufacture of zinc chloride or iron sulphate. If an analysis of the causes enumerated in the table be made, it will be found that the causes may be grouped under various heads, viz.:—

TABLE III.

Group Heads.		Number of Cases.
1. Chemical Operations in Laboratories—		
(*a*) Operation with *known* arseniferous materials	= 8	
(*b*) ,, ,, *unknown* ,, ,,	=14	
	—	22
(*c*) ,, not known		1
2. Trade processes		73
3. Military ballooning		16
4. Domestic environment (wall-papers)		6
5. Causes not known		2
Total cases		120

The laboratory experiments embraced the following, viz. :—

(*a*) Generation of hydrogen for respiration to produce Tyndall's experiment of the "shrill" voice; Cases IV., VI., X., XIII., XXI.

(*b*) Demonstration to students of AsH_3 by Marsh's test; Case V.

(*c*) Intentional generation of AsH_3 for experimental purposes; Cases I., II., III., XXX.

(*d*) Testing for arsenic in the viscera of a poisoned girl by Marsh's test; Case VIII.

(*e*) Other experiments with arsenical compounds; Cases XXVIII., XXXII.

The trade processes include the following, viz. :—

(*a*) Researches in, or manufacture of, anilin colours; Cases VII., XIV., XVII., XXIII., XXIX.

(*b*) Filling of toy balloons with hydrogen; Cases XII., XX., XL.

(*c*) Accidental addition of arsenic acid for sulphuric acid in hydrogen lamp for brazing purposes; Case IX.

(*d*) Extraction and treatment of ores; Cases XI., XXV., XLVI.

(*e*) Manufacture of zinc chloride and sulphate; Cases XV., XVI., XXVII., XXXI., XXXIII., XLIV.

(*f*) Utilisation of galvanisers' zinc flux skimmings; Case XXII.

(*g*) Manufacture of bleaching-powder; Case XLI.

(*h*) Brazing by the hydrogen flame; Cases IX., XLIII.

(*i*) Galvanising; Case XLII.

(*j*) In military ballooning, cases have arisen during the inflation and deflation of balloons filled with impure hydrogen; Cases XXIV., XXXIV., XXXVI., XXXVII.

(*k*) Galvanic processes; Case XLV.

(*l*) Tank-cleaning; Case XLVII.

From the foregoing it is evident that cases exhibiting the toxic effects of hydrogen arsenide may arise in a large variety of occupations and enterprises. But if we take the fundamental cause of their occurrence, it is apparent that they arose solely from the presence of arsenical impurities in the reagents employed to generate hydrogen, or from the impure hydrogen liberated in the chemical reaction.

It might have been expected that chemists and scientists would not have been found in the list of victims and sufferers from this form of intoxication, owing to their knowledge of the arsenical impurity which such chemicals contain; but, as the list indicates, it seems too frequently to have been taken for granted that the chemicals used were pure, and hence mishaps arose. It is very obvious that the observance of the simple precaution of ascertaining, before any experiment is made in which hydrogen is to be, or may be, evolved into the atmosphere of a laboratory, that the reagents are arsenic-free, will effectually safeguard against such deplorable occurrences being repeated.

In addition to the foregoing list of causal conditions, there fall to be noticed certain others, and of these the

first to be noted is the evolution of this arsenical gas in and from electric batteries in which sulphuric acid is employed. M. Grommier de Lyon has recorded [1] a certain number of cases of poisoning among persons employed continuously in a confined space in which the electric current was generated by means of bichromate of potash cells. In this instance, as in others, it was found that the cause was arseniferous sulphuric acid. Similar results have followed in a galvanic process for the recovery of copper (Case XLV.), p. 201. Lucas [2] also points out how, for the same reason, like results may arise in the manufacture of iron sulphate. On one occasion, he states, Professor Layet was making a visit to a chemical work, when he perceived the garlicky odour characteristic of hydrogen arsenide apparently arising from a vat in which, it appeared, ferrous sulphate was being made from scraps of old iron by solution in sulphuric acid. On putting some of the material from the vat into a Marsh apparatus, Layet was able to demonstrate the marked presence of arsenic in the acid by the AsH_3 which was liberated.

Roasting of arseniferous ores is also liable to be attended by similar manifestations of poisoning, but it is not clear in all cases that the cause of the toxic results is this particular gas, although at the same time it seems undoubtedly to be some gaseous or vaporous form of arsenic. Danger always exists, therefore, in the roasting of those ores which are usually associated with arsenic, such as iron pyrites, iron and copper pyrites, and cobalt ores. Some risk, also, is incurred in the manufacture of cobalt blue, which is a compound of aluminium and the protoxide of cobalt.

[1] *Acad. de Méd.* April 10, 1877.
[2] *De l'Empoisonnement par l'Hydrogène Arsénié*, Paris, 1895.

The following table tries to summarise the professions and occupations, the members of which are exposed to risks of poisoning by hydrogen arsenide.

TABLE IV.

I. Professional chemists.
   (*a*) In medico-legal analyses in cases of arsenical poisoning.
   (*b*) In preparation of AsH_3 for demonstration purposes.
   (*c*) Researches in anilin colours and in arsenical compounds.

II. Physicists and Physiologists.
   (*a*) Inhalation of arseniferous hydrogen in experiments on the voice, or as to pulmonary capacity, or other like experiments.

III. Workers in anilin colours.
   (*a*) Preparation of arsenic acid; working at retorts; treatment of raw materials.

IV. Chemical workers.
   (*a*) Manufacture of iron sulphate.
   (*b*) Manufacture of zinc chloride and sulphate.
   (*c*) Zinc-smelting.
   (*d*) Roasting and extraction of mineral ores.
   (*e*) Manufacture of bleaching-powder.
   (*f*) Manufacture of soda sulphate by treatment of soda lye with arseniferous sulphuric acid.

V. Ballooning for military and other purposes.
   (*a*) Inflation and deflation of balloons.
   (*b*) Leakages during balloon flights.

VI. Plumbers.

VII. Galvanising.

To this subject of ballooning some detailed attention must be given.

Of late years, probably the most common occupation associated with poisoning by this gas is ballooning, and particularly the operations of inflating and deflating

balloons, although it has even been found associated with balloon free ascents. Attention has frequently been called, especially by Continental writers, to this. Among other writers on this aspect of the subject may be named Maljean, Durand, Oulmont, Crone, Granjux, and others. Probably of these the first-named has given most attention to the subject. In a paper on "Intoxication par le gaz hydrogène arsénié chez les aérostiers,"[1] he enters very fully into the subject.

He points out that arseniuretted hydrogen is constantly found in the hydrogen employed in filling balloons, because it is manufactured from impure reagents. The accidents to aeronauts and those who work with balloons are often less grave than in other circumstances, although the death-toll among balloonists and those associated with them has not been small.

In military ballooning, hydrogen is exclusively used, because it is the lightest of all the gases, and is the easiest to manufacture. In regular military establishments the gas is made in special apparatus from the action of sulphuric acid on iron, but sometimes zinc is used in place of the iron. At a distance from ordinary facilities of manufacture in this way resource is had to the use of compressed hydrogen in steel cylinders, the pressure employed being 120 atmospheres. If the reagents were pure, the hydrogen evolved would be devoid of any foreign gas, and consequently would not be toxic. Besides, as Maljean points out, when pure it possesses the maximum of those qualities which best befit it for ballooning. But owing to the need of manufacturing the gas quickly in large quantities and in a fresh condition, commercial methods have come to be adopted, and from commercial

[1] *Arch. de méd. et pharm. mil.* 1900, vol. xxxv. pp. 82-102.

products which are always more or less impure. Sulphuric acid made from pyrites contains a relatively large amount of foreign matter, amongst which are arsenious oxide and arsenic oxide. Certain Belgian pyrites, he tells us, contains from 2 per cent to 5 per cent of arsenic in the form of arsenite of iron, and other pyrites contain both arsenical and selenium compounds. When prepared, however, from sublimed sulphur, the acid may be considered to be free from arsenic, at least in such amounts as to be harmful. The metal used in France in making hydrogen for filling balloons is generally iron in the form of iron turnings or shavings of steel and of castings, which can be bought at a low price as the waste of certain metallurgical industries. All of these contain a certain amount of arsenic associated with carbon, phosphorus, sulphur, and silicon. The source of the arseniuretted hydrogen is not far to seek. Manufactured as above, the gaseous product always has a disagreeable and complex odour, in which, however, the garlicky odour predominates. In view of the elements commonly found in the iron or steel employed, it is not surprising that, in addition to the arsenical gas, other gases as H_2S, PH_3, SeH_3, SO_2, CO_2, and other carbon gases are to be found admixed with the hydrogen. Apart from their poisonous properties, the presence of these adventitious gases is a positive disadvantage relative to the purpose for which the hydrogen is wanted. Being heavier than hydrogen, they make the product heavier, and consequently cause it to lose some of its ascensional power. Moreover, as experience has proved, some of these gases exert a distinctively destructive effect on the material of which the fabric of the balloon is made, and hence this adds to the danger of ballooning. In one case, for example, when the interior of the fabric

was examined, it was found covered with a fine brownish-coloured powdery material, which on analysis was found to contain arsenic and selenium.

The apparatus in use in the military establishments in France is the invention of Colonel Renard. It is a circulatory apparatus, in which the gas is generated, washed, dried, and verified as to ascensional power. It consists of the following parts, viz.:—(1) the *generator*, into which the metal and acid are placed, and in which is an arrangement whereby the iron sulphate formed in the reaction is diverted automatically toward the exterior; (2), the *washer*, into which the liberated gas from the generator passes, and where it is met by a sheet of cold water, which is constantly being renewed, by which it is supposed to be washed or scrubbed free of certain of its contained adventitious gases; (3), the *dryer* or *desiccator*, in which is placed caustic lime, or a mixture of caustic lime and of wood sawdust moistened with iron sulphate solution; and (4) the *tester or verifier*, by which the contained amount of watery vapour in the gas is ascertained; and, last of all, an apparatus by which the ascensional power of the gas is estimated.

The question next to be asked is, What is the effect of these united operations on the purity of the gas? It is known that hydrogen is fourteen times lighter than air, and that, when pure, a cubic metre of the gas should weigh 89 grammes. In practice, however, it has been found that the product obtained from the foregoing process rarely weighs less than 150 to 200 grammes, which fact alone is the proof that other gases than hydrogen are present, and these not in small quantities. The presence of hydrogen arsenide betrays itself in the product by its alliaceous odour; but, in addition, its presence may be

demonstrated chemically by the effect of the gas on a piece of filter paper moistened with a strong solution of silver nitrate placed in the stream of the gas. If hydrogen arsenide be present, the paper will show, probably by the end of an hour, certain black stains due to reduction of the silver to the state of oxide, and certain other brick-red stains of arseniate of silver. Maljean accounts for the presence of the arsenical gas after the foregoing treatment in the following way: The hydrogen and other gases, as they leave the generator, are at a fairly high temperature, and are saturated with watery vapour, besides containing solid and liquid particulate matter. When the gases reach the washer, the watery vapour is for the most part condensed and is freed from these solid particles. Some of the contaminating gases are very soluble in water, as CO_2, H_2S, and SO_2, and are therefore arrested. Others, however, are less soluble, as, for example, AsH_3, which requires five volumes of water for its solution, and resists solution even more than SeH_3; thus it appears in practice to be little affected in the washer. In the desiccator, the gas gets rid of any remainder of watery vapour, and the lime arrests any CO_2 and sulphur gases. The iron sulphate in the sawdust arrests the H_2S and analogous gases. But the contact of the gases during the circulatory process seems to be too short to have much effect in arresting thoroughly these gases, and besides, the mixture of sawdust and lime is apt to become saturated comparatively quickly: thus the gas is not deprived to any great extent of the arsenical gas.

Of the other papers which deal with this question, the following may be cited, viz. Durand,[1] "Intoxication des

[1] *Annales d'hyg.* 1900, 3rd ser., xliv. pp. 35-38.

aérostiers par l'hydrogène arsénié," and Granjux[1] bearing a similar title.

In lead-burning operations, especially those which are being conducted in confined or ill-ventilated places, dangers may arise from the arsenical gas which is present whenever the acid or zinc, or both, used for generating hydrogen for the brazing lamp are arseniferous. Case XLIII. is an example of this kind.

[1] *Bulletin médical*, April 14, 1900, p. 354.

CHAPTER III.

SYMPTOMS OF POISONING.

THE symptoms which usher in the poisoning by this gas, while they are indicative of the operation of a profound cause upon the system, cannot be looked upon as characteristic or pathognomonic of this particular form of poisoning, since many or most of them individually or in small groups are common to other conditions with which they may, at first at least, be reasonably confounded. Their incidence and sequence, however, are characteristic, inasmuch as they point to the operation of a poison within the body, and especially to the action of a poisonous gas when the incidence, development, and range of symptoms are fully reviewed.

In not a few cases the interval which elapses between the period of exposure to the gas and the onset of the more definite symptoms is sufficiently long to prevent the causal relationship of the one to the other to be clearly perceived; at the same time, in several other cases the period of onset is almost coincidental in point of time with the period of exposure, or at most is only separated therefrom by an interval of time which varies from minutes to a few hours.

Period of Onset.—The time of onset of symptoms after exposure to the gas, where only hydrogen arsenide is present, depends obviously upon two factors, viz. (*a*)

the percentage volume of the gas in the atmosphere breathed, and (*b*) the condition of the person at the time of exposure. The latter, however, is probably of minor importance compared with the former, and operates but in a limited way.

To these may be added, in certain very rare instances, the presence in the same atmosphere of other poisonous gases, such as antimoniuretted hydrogen.

From a rapid glance at Table II. App., it will be seen generally that the symptoms begin to appear from a few minutes up to twenty-four hours after exposure, the average period being from three to six hours.

There can be little doubt, moreover, that the time of onset is largely affected and determined by the nature of the operation in which the gas is being evolved, the relation of the workers thereto, and also by the character of the work-place with respect to ventilation. Where the gas has been inhaled as an unknown adulterant, the symptoms are fairly constant as to the time of appearance. While, also, the element of non-ventilation or of imperfect ventilation of the work-place is operative more or less prejudicially, a careful examination of the recorded cases will reveal that, even where the operation is conducted in the open, poisoning equally followed, and sometimes in a very unexpected fashion as to its incidence upon those engaged. Hydrogen arsenide having a greater specific gravity than air, and therefore being more likely in certain conditions of want of ventilation to be found in the lower strata of the atmosphere in the work-place, might be expected to act more constantly and uniformly in such circumstances. Instead of this being the case, however, the gas presents grave anomalies of action, and the factor which evidently determines its action upon a

series of individuals so employed at the same operation is the presence or absence of local currents of air which tend to irregular distribution of the gas. This is very apparent in the series of cases recorded on p. 165, which occurred at Accrington. There the men who were working nearest the point of generation of the gas, viz. on the platform, were the least, and those in the well at a lower level were the most seriously affected, while even of those on the platform, one was severely poisoned, one was but slightly attacked, and a third escaped entirely. At the same time, in places where ventilation did not practically exist at all, as in the Wolverhampton cases (p. 141), the Irvine cases (p. 179), and others, the effects upon the workmen were more disastrous.

Obviously the lethal character of the gas essentially depends upon the precise quantity of it which has been inhaled, and therefore, in general terms, the length of time of exposure to its influence will be indicative of the percentage amount of it in the atmosphere breathed by the person at the time. We must, however, discriminate between those cases in which impure hydrogen had been inhaled intentionally for experimental purposes and those in which it was inhaled accidentally as part of the ordinary atmospheric environment of the individual worker, because in the former the adventitious arsenical gas, being directly inhaled as an unwitting component of the hydrogen, exercises a more rapid and effective striking action.

Nature and Character of Symptoms.— Although in individual cases one particular symptom may be described as being more specially marked and prominent at the outset, and may be specially referable to one organ of the body, the earlier symptoms may be summarised as follows:—(1) an indefinable feeling of illness and of great

weakness; (2) giddiness; (3) faintness; (4) pains in head and epigastrium; (5) coldness of body; (6) sense of oppression of breathing; accompanied, in some cases, by some measure of cyanosis; and (7) nausea, sickness, and vomiting.

These are quickly followed by (1) continuous vomiting of bilious matters at first, and, later, of bloody material; (2) jaundice, which may vary in tint from golden yellow to mahogany, ranging through coppery, bronze, and mulatto tints, which extends usually over the whole body, but which, in lighter cases, may be located solely in the conjunctivæ; (3) thirst and dryness in the throat, with weakness of voice; (4) pains in the loins; (5) pains or sense of fulness over the region of the liver; (6) hæmorrhages from one or more different parts of the body; (7) hæmoglobinuria or hæmaturia, oliguria, and, in cases going on to a fatal termination, anuria; and (8) clear intellectivity, but sometimes, minor degrees of stupor, although generally before death supervenes some measure of unconsciousness, with or without delirium.

In addition to these symptoms, and mostly towards the end, hiccough and subnormal temperature are found, while physical examination of the body of the patient will reveal in most cases enlargement of the area of dulness of liver and spleen. Probably the most outstanding symptoms, and those which should lead to a suspicion of poisoning by this gas, especially where there is a history of exposure to gaseous emanations, are the following, viz. (1) severe nervous shock; (2) bloody urine; (3) jaundice of a more or less coppery colour which quickly supervenes; and (4) alterations of the blood, as seen on microscopic examination.

The following detailed description of the symptoms will assist to complete the clinical picture.

If those cases be first considered in which hydrogen containing a certain unknown admixture of AsH_3 was inhaled for experimental purposes, the time of onset and the character of the symptoms may be better studied. Nine of the cases hereinafter narrated (IV., VI., X., XIII., and XXI.) had their origin in this way. Of these, two deaths resulted. The symptoms came on immediately after the inhalation. They consisted of giddiness, fainting, general feeling of illness, and unsteadiness of gait, and were succeeded by shiverings and by pains in the loins. More or less quickly after these supervened bloody urine and hæmorrhage from the nose or bowel, together with jaundice.

In another series of cases (I. and III., involving three persons) in which AsH_3 was being intentionally generated, and in which the effluent tube was sniffed deliberately to discover the precise moment at which the gas began to be evolved, the symptoms also developed with marked rapidity. Moreover, this series is of considerable interest as affording some approximate indication of the very small amount of the gas necessary to produce serious effects. In none of the three cases of this series could much of the gas have been inhaled; yet, notwithstanding, within an hour thereafter, the symptoms began to exhibit themselves in the form of intense headache, vertigo with buzzing in the ears, vague uneasiness, feeling of great weakness, burning thirst, muscular inco-ordination of the lower limbs, shiverings, jaundice, and bloody urine. The reader is referred to Case XXIX. for a graphic description of these symptoms and their incidence.

The remaining cases might be divided in further series, such as those in which the arseniferous gas was being intentionally worked with, and those in which it was

accidentally present in some other chemical operation; but this would not serve any particularly useful purpose. We therefore confine our observations to the significance of the symptoms themselves.

The keynote of the symptomatology would seem to be the rapid dissolving or hæmolytic action of the gas upon the blood corpuscles, and the resulting incapability of the corpuscles to convey sufficient oxygen to the different organs of the body, together with the inability of the emunctory organs, liver and kidneys, to cope with the elimination of the dissolved hæmoglobin. The symptoms, therefore, have direct relation, first, to the effect upon the organs of this imperfect or disorganised blood-supply, and, second, to the effect upon those organs by which the poison itself and the products of the disintegrated blood-corpuscles are eliminated from the body.

I. Effect upon the Bodily Organs due to Impure and Imperfect Blood-supply.

With reference to the nervous system, it will be evident that the effects on the brain are indicated by the giddiness, pains in the head, inco-ordination of thought or inability to concentrate thought, flashes of light before the eyes, buzzing in the ears, and unusual sensitiveness to jarring sounds, and on the spinal cord, by muscular inco-ordination of the lower limbs and tingling of the limbs; while on the general nervous system they are indicated by the indefinable feeling of uneasiness, illness, and weakness, and by coldness of the body and shiverings.

The effects on the heart are shown by the feeling of faintness and by feebleness of pulse: and on the lungs by the sense of oppression of breathing without any accompanying physical evidence of lung lesion, due to the increased systemic need for oxygenisation of the blood.

II. Effect upon Organs by which Poison and Products of Blood-disintegration are eliminated.

The organs mainly involved under this category are the stomach, liver, kidneys, spleen, and, in varying degree, the intestines. The action of the poison circulating in the blood upon the stomach corresponds very closely to the action of the same poison when ingested. Vomiting is a constant feature of all the recorded cases, and it was of a severe, persistent, and continuous character. The vomited matter consists at first of the ordinary contents of the organ, then of bile-tinged fluid, and latterly of bloody matter either of the "coffee-grounds" character, or of more or less pure blood. It would thus appear as if arsenic, by whatever channel it is taken into the body, has an elective action upon the stomach, and the organ may in this light be reckoned as one of the normal emunctories or eliminating organs of the poison from the body.

The action of the gas upon the liver is indicated by the jaundice, that is through its hæmolytic action on the blood-corpuscles. It will be noted that jaundice, of varying tints in lighter cases, and of a coppery or bronze hue in severer cases, was present. Indeed, this may be looked upon as one of the chief outstanding symptoms of this form of poisoning.

The cause of the phenomenon is discussed in a separate chapter, therefore it is only now necessary to note the constancy of the phenomenon itself. As a direct result of the importation to the liver of a blood-supply abnormally charged with disintegrated products, enlargement of the organ is usually found to exist, as is indicated by increase of the area of dulness. In this way, also, is accounted for the feeling of fulness or tension in the

region of the organ, so often complained of by persons attacked.

The kidneys likewise share prominently in the general distress. Early in the history of a case, pains in the loins, sometimes to a marked degree, assert themselves, and accompanying these is a strong desire at first for micturition. The kidneys being among the chief organs by which arsenic in any form is eliminated from the body are always involved to a greater or lesser degree; and this difficulty in functioning is increased further by the fact that the disintegrated blood-products seek by these channels an outlet from the system. The effect of both is the production of bloody urine and a proliferative nephritis. Blood-coloured urine is an early and constant feature in these cases, and it persists for a variable time after cessation of more serious symptoms. While oliguria is most commonly present, it must not be forgotten that in certain isolated cases it may not be a prominent feature. In most of the cases ending fatally anuria usually is established for some time prior to death. This is in all likelihood due to the nephritis which is set up, from which also undoubtedly originate the symptoms of uræmia which are found in certain of the recorded cases.

The spleen, too, shares in the blood disturbance. In several cases it has been found enlarged during the life of the patient. The intestines exhibit alterations in function which must be reckoned as part of the eliminating process referable to arsenic. Diarrhœa is not an uncommon symptom, and bloody stools are also by no means rare.

With regard to the occurrence of hæmorrhages during the currency of such cases, it ought to be said that they are consequent upon the dissolved condition of the

hæmoglobin in the blood-stream, and to fatty degenerative changes in the capillary vessels. These hæmorrhages may assume the form of melæna, purpuric skin eruptions, epistaxis, or bleeding from the gums, the prepuce, or even the glans penis.

Table II., Appendix, summarises (*a*) the time of onset of symptoms in the cases recorded, (*b*) the time of exposure to the gas, (*c*) the initial symptoms, and (*d*) the incidence of (1) hæmoglobinuria, (2) jaundice, (3) oliguria, and (4) anuria.

CHAPTER IV.

CAUSE OF THE JAUNDICE.

THE intimate cause of the jaundice in this form of poisoning has long been a vexed question, and much has been written and many experiments on animals have been performed to elucidate it. It is not clear, indeed, even now that a uniformity of view has been reached. The crux of the question has always been whether the jaundice originates in the liver or in the blood, or partly in both: whether, in other words, its source is hepatogenous or hæmatogenous, bilipheic or hæmopheic. The interest in this question probably had its origin in the fact that, along with the jaundice which is uniformly present in some measure, this gaseous poison has the power to liberate by its hæmolytic action the hæmoglobin from the stroma of the red corpuscles, and so to allow it to pass into solution in the blood plasma; and it was believed that it was because of this fact that the urine which is passed soon after the onset of toxic symptoms should be highly charged with blood-colouring matters.

For a long time, opinion was sharply divided on the subject, but perhaps only so long as the question was solely or mainly considered from the speculative point of view. This academic discussion did not, however, substantially contribute to the scientific knowledge of the subject. It became clear that two methods only were available by

which the truth could be ascertained regarding the cause, viz. (*a*) clinical observation, and (*b*) experimentation on animals. The former, however, could only illustrate the effects of the operation of the poison, and be supplementary to the latter, whereby the mode of action of the poison could be followed stage by stage by preparative methods, such as cutting off the circulation of the liver from the general circulation, or even by the extirpation of the liver itself.

The whole question of the relationship of the blood-pigments to the bile-pigments came thus to be opened up; and, in addition, the aid of the knowledge of chemical processes in the bodily economy had to be invoked.

Probably one of the first incentives to the study of the subject arose from the discovery made by Virchow in 1847 that in blood extravasated into the living tissues a certain metamorphosis of blood-colouring into bile-colouring matters took place. From this was suggested the inquiry whether in certain forms of icterus, particularly such as those which occurred where there was no mechanical obstruction to the outflow of bile—and by this is meant even catarrhal obstruction,—the icterus could be due to such a metamorphosis taking place within the living circulation without the intervention of the liver. The answer at first given to this interrogation was in the affirmative, and thus it came to be assumed that there did exist a hæmatogenous form of jaundice as well as a hepatogenous form, the latter arising from a re-absorption of the bile from the liver into the blood. But in respect that the former name committed those who adopted it to a definite theory as to its cause, and thus did not meet the views of those who were not so clear as to its origin, but who at the same time believed that there was a form

which had not its origin in the liver, Quinke[1] suggested the name of "anhepatogenous" jaundice, thus getting rid of the view that its production was necessarily due to the blood, while preserving, at the same time, the idea that its source might be other than in the liver.

Then followed the experiments and observations of Kühne.[2] In 1866, however, Leyden in his contributions to the pathology of icterus[3] tried to distinguish clinically between the two forms of jaundice, and he came to the conclusion that the best test whereby to distinguish the anhepatogenous from the hepatogenous form was to determine the presence or absence of bile-acids in the urine. He declared from his experience that the bile-acids could not be demonstrated in the urine of the first-named form, but could be discovered by appropriate tests in the urine of the last-named.

In 1868, Naunyn[4] subjected the question to the crucial test of experiments upon animals. His experiments were made mostly upon rabbits, but were negative in respect of the discovery of bile-acids in the urine.

Clinical experience had, however, in the meanwhile, demonstrated that other conditions and substances than hydrogen arsenide could produce solution of the hæmoglobin in the blood-stream; such, for example, as extensive burning of the body, paroxysmal hæmoglobinuria, hæmoglobinuric or "black-water" fever, transfusion of blood, severe infections, and other forms of intoxication, as by potassium chlorate and pyrogallic acid. The general opinion therefrom was that the cause of icterus was to be found in the conversion in the blood-stream itself of the

[1] Virchow's *Archives*, Bd. 94, 1884. [2] *Ibid.* Bd. 14.
[3] *Beiträge zur Pathologie des Icterus*, 1866.
[4] Reichert und Dubois, *Archives*, 1868.

blood-pigment into bile-pigment: consequently the belief in an anhepatogenous form of jaundice persisted.

Stadelmann, in an article "Ueber Toluylendiamin und seine Wirkung auf den Thierkörper, Beitrag zur Lehre vom Icterus,"[1] gave the results of experiments on dogs as to the poisonous action of toluylendiamin, from which he observed that among the effects produced were icterus of the tissues, hæmoglobinuria, and the presence in the urine of bile-pigment and bile-acids. In the post-mortem examination of these dogs, he found a very marked thickening of the bile and distension of the gall-bladder and ducts with tough, tenacious or inspissated bile, which deposited a considerable amount of amorphous sediment and numerous crystals of bilirubin. He noted, besides, that the more severe the icterus, the more markedly was the bile thickened and the gall-bladder distended. From these facts he concluded that, by reason of the difficulty which such bile experienced in passing through the common duct into the intestine, the resulting engorgement or stasis caused its absorption into the blood, and therefore icterus of the skin and tissues to ensue. This discovery of bile-acids in the urine indicated a jaundice by absorption of bile products from the liver, and proved, for this toxic substance at least, which exercised a hæmolytic action, that the jaundice was not hæmatogenous but hepatogenous.

The same observer found by further experimentation on dogs poisoned by hydrogen arsenide that the gall-bladder and gall-ducts were likewise filled with tough or inspissated bile, and, further, that the bowel contained a large quantity of that fluid. On a dog in which a biliary fistula had been established, he experimented with this

[1] *Archiv. für experimentale Pathologie und Pharmacologie*, Bd. xv.

gas, and he observed that although the total quantity of bile secreted in twelve hours was diminished to about one-third of the average total amount, the relative amount of bilirubin was increased three and a half times above the normal.[1] Likewise the bile became dark in colour and thick and tenacious in consistence.

From all these observations, therefore, he reached the conclusion that, although this gas undoubtedly exercised a marked solvent effect upon the hæmoglobin of the living blood, the blood itself was not the source of the jaundice, but that the source of the jaundice was the liver, which by reason of the abnormal blood and abnormal nutritive material imported to it, produced an abnormal bile rich in bile-pigment, but poor in bile-acids and water.

Notwithstanding these researches, he approached the solution of the question in another way, viz. by injecting into dogs pure crystalline hæmoglobin, thus simulating to some extent the condition of the blood after the exhibition of hydrogen arsenide.[2]

From these experiments, also, he found the same general effects produced, viz. a reduction in the total secretion of bile and the formation of a tough, tenacious bile, rich in bile-pigment. These experiments were followed by other series of experiments by other observers. Stern[3] injected into rabbits varying proportional amounts of hæmoglobin. He found that when the amount injected exceeded 0·02 gramme per kilo. of body-weight of animal, the liver of the animal was not able to change the extra blood-pigment into bile-pigment, and consequently that some part of the surplus amount presented itself unchanged

[1] *Archiv. für experimentale Pathologie und Pharmacologie*, Bd. xxiii., 1887.
[2] *Ibid.* 1888.
[3] Virchow's *Archives*, 1888.

in the bile. If, however, the quantity injected much exceeded the proportion named, hæmoglobinuria made its appearance.

Gorodecki's experiments consisted of injecting into dogs, either subcutaneously or *in peritoneo*, hæmoglobin solution, and these showed that the secretion of bile-pigment was increased to the extent of 60 per cent.

Schmidt [1] has given as his opinion that free hæmoglobin under ordinary circumstances is changed by the liver-cells into met-hæmoglobin as a preliminary step in the process by which it is ultimately converted into bile-pigment.

Kobert [2] is of opinion that between the condition of met-hæmoglobin and bile-pigment there is an intermediate state of the colouring matter, which, although it bears a somewhat close resemblance to hæmatin, does not quite correspond to it, since it does not give a spectrum. It has not yet been clearly demonstrated that this intermediate colouring matter is bilirubin, but it corresponds to it in the negative fact that, like bilirubin, it yields no spectrum, and therefore is a substance which does not contain iron. It would appear, therefore, that in the liver the iron of the hæmatin is set free by the action of the hepatic cells, and is probably retained by them, since bilirubin is an iron-free substance. In bilirubin, however, which is eliminated in ordinary bile from the liver, there is a certain percentage of iron present, to the extent, indeed, of 1·4 to 1·5 per cent, whereas hæmatin contains about 9 per cent of that metal.

In order, therefore, to assume the likely production of bilirubin from hæmatin, we must suppose that somewhere in the animal economy the iron is separated and

[1] *Biolog. Centralblatt*, 1890.
[2] *Lehrbuch der Intoxikationen*, 1893.

stored up for future use. All observations point to the liver as the organ in which this is most likely to take place. On this hypothesis, then, Nencki and Sieber have suggested the following chemical equation as representing the change which occurs, viz.:—

$$\underbrace{C_{32}H_{32}N_4O_4Fe}_{\text{Hæmatin}} + 2H_2O = Fe + \underbrace{2C_{16}H_{18}N_2O_3}_{\text{Bilirubin}}.$$

There can be little or no doubt that the source of bile-pigment is the blood-colouring matter, but whether the precise route which is followed in the process of conversion has yet been unmistakably tracked out is not yet definitely settled.

Hammarsten [1] discusses at close quarters this definite question, viz. Do the specific constituents of the bile, the bile-acids, and the bile-pigments originate in the liver; and, if this is the case, do they come from this organ only, or are they also formed elsewhere? In essaying to answer these questions, he takes count of experiments made upon animals in whom the liver was either extirpated, or in whom the portal circulation was cut off by ligature from the systemic circulation. Obviously if the bile-pigments and bile-acids are not formed in the liver, or not only in the liver but are simply eliminated from the blood, bile will accumulate in the blood and tissues in such experiments as the foregoing. On the other hand, if these are formed wholly or chiefly in that organ by the action of its cells, then removal of the organ would prevent such a result; or, again, if the common duct be tied, the bile constituents will collect in the blood and tissues, whether they are formed in the liver or elsewhere in the body.

[1] *Text-book of Physiological Chemistry*, 1893, p. 159.

Kobner's experiments on frogs point to the fact that bile-acids are produced solely in the liver. After extirpation of that organ, bile-acids could neither be detected in the blood nor tissues, whereas after ligature of the common duct they could be found. The investigations on dogs by Ludwig and Fleisch, conducted on similar lines, corroborated that conclusion. Stern's experiments on pigeons, in which the portal vessels and biliary ducts were ligatured, showed that at the end of twelve hours thereafter, no bile-pigments could be found either in the blood or tissues of these birds, but that at the end of five hours after the bile-ducts were tied, bile-pigments could be found in the blood-serum.

These experiments seem to us to prove that the formation of bile-pigment does not take place in the blood but in the liver. Consensus of opinion on this subject now appears to be that bile-acids are exclusively formed in the liver, and bile-pigment also under usual circumstances. It ought to be remembered, at the same time, however, that hæmatoidin, which is now held to be identical with bilirubin, may be formed in old blood-extravasations. This view is based upon the fact that hæmatoidin, though derived from the blood, shows no absorption bands in the spectrum, thus contrasting with other blood-pigments.

Frerichs experimented upon dogs by injecting pure bile into their blood in order to note the effects of the presence of an abnormal quantity of bile in the blood-stream. Of the twenty-nine experiments which he made, in nineteen did the urine exhibit a larger or smaller quantity of colouring matter than normal, and in these cases the total quantity of urine passed was small in amount, was of a greenish colour, and was neutral or alkaline in reaction.

After separation of the green flakes by filtration, the filtrate was found to be blood-red in colour, due apparently to dissolved blood-pigment, but no red blood-corpuscles could be found in the sediment. Chemical tests, however, demonstrated the presence of bile-pigment and the absence of bile-acids.

In view of the large number of experiments recorded, and of their results as bearing on the hæmatogenous or anhepatogenous source of jaundice in this form of poisoning, let us return to the consideration of the action of hydrogen arsenide in the causation of icterus and hæmoglobinuria.

The experiments of Minskowsky and Naunyn on geese and ducks in which the livers were extirpated, and which afterwards were exposed to atmospheres containing this gas, showed as effects the presence of hæmoglobin in the urine, but the absence of biliverdin, whereas in normal-livered birds after like exposures there was increase of secretion of bile as well as hæmoglobinuria. The former of these observers, collaborating with Basserin, has shown that in the abundant formation of bile-pigments which happens in this form of poisoning, the quantity of iron in the bile is not increased, and does not correspond apparently to that in the decomposing blood-colouring matters. Both observers are of opinion that the iron, for a time at least, is retained in the liver as a pigment rich in iron; and this view is corroborated by the observations of Minskowsky and Naunyn with respect to the livers of the geese and ducks experimented upon, where such a pigment was found.

On the general question, it would appear as if opinion among French physiologists was not so definitely decided as in Germany. Lucas[1] discusses the subject of jaundice

[1] *De l'Empoisonnement par l'Hydrogène Arsénié*, Paris, 1895, p. 87.

and the cause of its production in his thesis, and gives the views of the leading writers in France on this point. Lucas himself starts from the position that the pathogenic process of the icterus is singularly obscure. Gubler, he points out, admits two kinds of jaundice, the hepatogenous and hæmatogenous, the latter term, however, being used under some reservation. Dreyfus-Brisac indicates what Gubler exactly means by it. The hæmoglobin, says he, coming from the destruction of the corpuscles is transformed into biliary pigment, and is eliminated by the bile; but under the action of a morbid influence, such, for example, as poisoning, the liver becomes powerless to transform into bile the hæmoglobin thus set at liberty, and the colouring matter consequently accumulates in the serum, not without undergoing various alterations, however, in the circulation. This type of jaundice is characterised by the presence of urobilin in the urine; and since in poisoning by the arsenical gas urobilin is found in the urine, the natural conclusion is arrived at that this form of jaundice is of hæmatogenous origin.

Hayem, on the other hand, cannot admit the conclusion, declaring that hæmatogenous jaundice cannot exist, not only because hæmaphein—a generic name under which Gubler comprehends together the blood-pigments—does not exist as such as a chemically defined body, but because, also, no one has ever succeeded, outwith icterus, in detecting biliary pigments in the blood. Lucas argues that between the hæmopheic jaundice and pleiochromic icterus of Stadelmann there is little essential difference, except in the explanations offered by the latter as to its causation; that in both cases the over-abundance of free hæmoglobin in the blood-plasma is the prime cause of the hæmoglobinuria, and likewise of the jaundice; but that

Stadelmann asserts the jaundice to be a jaundice of resorption, owing to the incapability of the liver to cope with the unusual quantity of hæmoglobin sent to it in course of circulation, and that this, in turn, produces a vitiated form of thick, tenacious bile, which being unable, because of these properties and because of the deposition of a sediment, to flow out of the organ by the ordinary channels, is absorbed into the circulation. On a review of the evidence, therefore, Lucas concludes that until the non-existence of the hæmatogenous form is more certainly proved, he will provisionally stand by the theory of Gubler. From a careful survey of the whole field of experimental research, from the clinical symptoms which are manifested during life, and from the condition of the organs after death in cases of poisoning by this gas, it seems to us to be clearly proved that the jaundice is a resorption jaundice, and that the conclusions of Stadelmann are nearest the truth which declare that the liver, being suddenly supplied with abnormal blood, that is, blood abnormally charged with free hæmoglobin, secretes an abnormal bile which is viscous, tenacious, and difficult to flow, and that this viscosity is the factor which prevents its entrance into the intestine; hence the abnormal fulness of the gall-bladder and gall-ducts, and the consequent absorption. What, in brief, seems to happen is this: under average conditions of health, the effete blood-products are capable of being converted into bile by the liver, the iron being stored in the economy for further use, but when the liquor sanguinis becomes overcharged with dissolved hæmoglobin, as it does in different forms of poisoning, paroxysmal hæmoglobinuria, and other affections, the liver ceases to be able to cope adequately with the altered conditions, bile of a tenacious character is formed, and the surplus dissolved,

hæmoglobin finds, or tries to find, a point of discharge by the kidneys, whence it passes to the urine, giving rise to the colour-appearances and constitution of the urine found. As corroboratory of this view, it is a noteworthy fact that, in all of these conditions and affections, the liver is usually found to be enlarged, the bile-ducts and gall-bladder to be distended with bile, and the kidneys to be swollen, their tubuli uriniferi being choked with exudation-débris, hence the jaundice, the oliguria, and even the anuria.

But while the conditions in hæmoglobinuric fever, so far as the blood is concerned, are on all fours with those in poisoning by the arsenical gas, there are still those who think with Manson that the jaundice produced in the former may, not improbably, be produced by a hæmoglobinæmia and not by a cholæmia; in other words, that there are good grounds for believing still the doctrine of an anhepatogenous form of jaundice.

One of the latest writers on the origin of the jaundice arising in poisoning by this gas is Maljean.[1] He remarks that the jaundice, considered by itself, is of a distinctive clinical character. The skin and conjunctivæ do not have the yellowish tint of biliary jaundice. The shade of colour is greenish, and recalls, in a more marked degree, the colour of certain chloroses. The condition of the digestive tract differs essentially from that of ordinary jaundice. It is true that at the commencement of the toxic attack there are likely to be sickness, diarrhœa, and, exceptionally, vomiting. But these symptoms supervene suddenly and disappear in some days; they are not simulative of the lingering gastric state which precedes and which follows catarrhal

[1] *Archives de méd. et de pharm. militaires*, 1900, vol. xxxv. pp. 82-102.

jaundice. The tongue conditions differ. There is neither pain nor swelling in the region of the liver. We do not find cutaneous itching, xanthopsy, or yellow sweat. In short, the icterus of these patients resembles jaundice only at first sight. Besides, the conditions of the urine are contra-indicative of catarrhal jaundice. Although of a coffee-black colour, it gives a reddish colour by reflected light, and not the greenish colour of ordinary jaundice tested in like manner. Moreover, the absence of biliary pigments, together with the presence of hæmoglobin in large amount, indicates that something different from ordinary bilious urine exists. Separated from its normal support in the blood-cells and dissolved in the serum, the hæmoglobin becomes a foreign element in the blood-stream, and as such is destined to rapid elimination. But before elimination it circulates in the blood, it impregnates all the tissues, and it communicates to them its peculiar coloration. In the skin and conjunctivæ it shows itself as a greenish-yellow tint characteristic of hæmatogenous jaundice. The intervention of the liver and bile is in no wise necessary to explain the jaundice. To prove this, he says, the facts of daily observation are more demonstrative of the cause than vivisections practised upon the biliary apparatus of animals at the cost of very intense functional troubles. He draws a parallel between the local results on the tissues of a subcutaneous extravasation of blood and the more general effects of the arsenical gas on the blood-stream, and urges that in the gamut of colour-changes which is undergone by the tissues in the local lesion there is reproduced a tint which corresponds to that observed in the toxic effects of the gas. Besides, he adduces the fact that after extensive contusions, when resorption of large sanguineous effusions

takes place, a general jaundice sometimes results, which Poncet[1] calls traumatic hæmatic jaundice, and which, although never very intense, nevertheless exists. Nor does this have its origin in the resorption of biliary matters, because these are absent from the urine. He ranks with this, also, *icterus neonatorum*, which is found in feeble infants who have suffered during labour, and which, in such cases, he believes to be due to the resorption of the blood from the caput succedaneum or other effusions of blood of a subcutaneous character, so common during such difficult labours. The urine in these cases does not contain biliary acids, but often crystals of hæmaphein and hæmatoidin. From these observations, therefore, it will be apparent that Maljean, like other writers and observers, is inclined to the view that the jaundice of poisoning from arseniuretted hydrogen is hæmatogenous rather than hepatogenous.

[1] *De l'ictère hématique traumatique.*

CHAPTER V.

POST-MORTEM APPEARANCES.

Of the 120 cases of poisoning which have been recorded from time to time in various theses, medical journals, and elsewhere, and which form the basis of this monograph, 37 ended fatally. Of this series, therefore, the results of 118 cases being known, the mortality rate was 31·36 per cent. This, however, must not be reckoned as the true mortality of the average hundred cases, because the total number of cases on record is far too small upon which even to base a relatively accurate rate. Of these fatal cases we are only able to present the results of the post-mortem examinations of 19, and some of the records even of these contain but the sparsest particulars.

Since the post-mortem appearances depend to some extent upon the period of survival of patients after exposure to the gas, it will be well to deal first with these periods in respect of the fatal cases. Table I., Appendix, shows at a glance the periods of survival. From the table it will be seen that the minimum period was two days, and the maximum the thirtieth day. From further examination of the table, it will be found that two deaths occurred on the second day, five on the third day, two on the fifth day, five on the sixth day, five on the seventh day, two on the ninth day, two on the tenth

day, and one each on the twenty-fourth and thirtieth day respectively.

Table III., Appendix, summarises the appearances found in the principal organs.

Since one of the most striking post-mortem appearances is the icteric discoloration of the skin and other structures of the body, this will be first considered.

Jaundice.—The icteric colour which may be seen at the necropsy of a series of bodies may probably range from a simple yellow tint to a light mahogany or bronze hue, but in marked cases of poisoning it will be of a bronze or coppery colour. Of course, to some extent the colour will depend upon the length of time the person has been exposed to the gas, and also to the period of survival after exposure. The jaundice is not confined to the skin and conjunctivæ, but, as might be expected, is also to be observed in the mucous membranes, and occasionally in the substance of the deeper organs, as liver or brain. The tone of colour observed on the abdominal wall after death differs somewhat from that on the body generally. Various recorders have noted its colour; and from Table II., Appendix, it will be seen that the colour may range from yellow through coppery to greenish or greenish-blue tints.

In some cases a blue line has been observed on the margin of gum and teeth, just as in lead poisoning. Besides the colour seen externally, certain colour-changes have been observed in some of the internal organs, but these will be discussed later. It only remains to be said that owing to the hæmolytic action of the poison, and the liberation of the hæmoglobin into the liquor sanguinis, it was to be expected that colour-changes would be more apparent in some organs than in others,

while all the organs more or less shared in the general disturbance.

Post-Mortem Appearances in Brain and Membranes.—In certain cases the brain and membranes have been found normal, while in those in which any record at all has been made the conditions have varied. Generally speaking, however, the meninges are found to be either anæmic and œdematous, or the dura mater is anæmic and the pia mater congested, while the substance of the brain itself is usually pale and anæmic. In individual cases the brain substance has exhibited an icteric coloration.

In Thoracic Viscera.—The lungs have generally been found collapsed and congested. The congestion may be confined, however, to the lower lobes, and accompanying the congestion there may be some degree of œdema. It is not surprising to find so little disturbance, comparatively speaking, of these organs when it is remembered that patients during life have practically no symptoms indicative of lung implication. It is quite true, at the same time, that in certain of the cases cyanosis was a marked symptom, but this was apparently due to the imperfect aeration of the blood consequent upon the destruction of the red blood-corpuscles and their inability to convey the necessary supply of oxygen to the tissues. From the congestion and œdema present during life, it might be expected that exudation-fluid would be found in the pleural cavities. The amount of this fluid varies in different cases, ranging from a few ounces in certain cases up to pints in others. Its colour has been variously described. It has been designated as of a reddish-brown or brownish-red colour, or in colour like bile, or even like blood itself. Its colour is significant of the dissolved state of the hæmoglobin, and it resembles nothing so

much as a serous solution containing dissolved hæmoglobin.

A similar fluid, in quantities varying from a few drams up to three ounces in amount, may be found in the pericardium.

In respect of the heart there are two important appearances, the first being ante-mortem and post-mortem clots, which are constantly found in different cavities, the second being fatty degeneration of the heart-muscle. The latter is of the greater importance, and sometimes plays a significant part in the proximate cause of death. This fatty change not only materially interferes with the ability of the organ to supply sufficient blood to the other organs and parts of the body, but it depreciates the integrity of the function of the heart itself, and tends to lead to sudden death. Indeed the history of some of the cases points to this as the cause of the sudden death which occurred. Another point which has been noted of the blood as seen *en masse* in the heart is its dark colour which may also be said to be characteristic of the blood generally. This is accounted for by the incapacity of the weakened or destroyed corpuscles to act as oxygen-carriers, and also by the reduced state of part of the oxy-hæmoglobin into met-hæmoglobin.

Abdominal Viscera.—The most noteworthy pathological changes in the viscera of this region are those which are found in the liver and kidneys, and which are, moreover, constantly found. The reason for this is that these organs have to deal with the unusual amount of dissolved hæmoglobin set free in the blood-stream. The rule is to find the liver more or less swollen and enlarged, due to the engorgement of its tissues from the bile stasis which occurs, and to the deposition of blood-pigment which

takes place in its tissues during the attempt on the part of the organ to cope with the abnormal blood conditions. Microscopic examination of sections of the structure of the organ shows granular deposits of brown-coloured pigment in the hepatic cells, particularly those in the vicinity of the hepatic vein, cloudy swelling of the hepatic cells, the nuclei staining with logwood, and, in addition, areas of fatty degeneration. Tests of the brown pigment for iron do not indicate the presence of that metal.

It may also be here noted that similar pigmentary deposits are to be found in the cellular structures of the heart, kidney, and intestine, as well as in perivascular tissues.

The colour of the liver is also changed in the bulk of cases. Although in rare cases the colour appeared normal, there was mostly some alteration in colour, which in different cases was seen to range from a simple yellow through greyish-brown, yellowish-brown, greenish-yellow, and slaty-blue to a deep indigo. The gall-bladder is found full of dark bile, in some instances to hyperdistension, and the bile itself is of a viscid, tenacious, stringy character.

Marked alterations are usually found in the kidneys, since by these channels the changed blood seeks exit from the body, and also because these organs are chief emunctories of the poison itself. The first notable change is that of colour, due in part to the hyperæmic state of the organs, and in part, possibly, also to the effects of elimination of the poison. In every case of fatal poisoning in which attention has been given to these organs on post-mortem examination, alteration of colour has been observed. The colours which have been recorded are—dark-red, brown, chocolate-brown, brownish-black, violet,

and indigo. The second change is enlargement of the organs, consequent upon the changes which have occurred in the intimate structure of the viscus. On microscopic examination of sections, the glomeruli are found to be swollen, the epithelial lining of Bowman's capsules detached or in a condition of proliferative swelling, the tubules are more or less full of broken-down corpuscles, and to be in a state of desquamative inflammation, forming casts which are either bloody, hyaline, or fatty.

Such conditions as these might, indeed, be expected from the pathological state of the urine, and from these pathological conditions can easily be explained the oliguria, anuria, and also the uræmia. The urinary bladder is usually found empty or to contain a very small amount of blood-coloured urine.

Urine.—This secretion has to some extent been examined in most of the cases, but in a few with respect only to the presence of blood. In every case hæmoglobinuria was present, and this lasted for variable periods. In the cases which ended fatally, oliguria and anuria usually preceded death. While oliguria was a constant symptom in practically all the cases, usually if the general condition of the patient improved, increase of flow of urine, even to polyuria in some instances, quickly took place. The specific gravity ranged from 1,007 to 1,032. Its reaction was usually weakly acid, but in one case it was found alkaline. The amount of hæmoglobin was estimated quantitatively in a single case, and in that, when the urine was at the point of highest colour, it amounted to 5·95 per cent. Albumin was found in every instance; and where quantitative estimations were made, the amount ranged from 0·11 to 0·06 per cent. The spectrum given by the blood-colouring matter in the urine

was commonly that of met-hæmoglobin, but in a few of the cases it was that of mixed oxy-hæmoglobin and met-hæmoglobin, while in one case it was said to be that of hæmoglobin, and in another that of acid hæmatin. The sedimentary deposit is always considerable in amount. Microscopic examination of it revealed the following as its common constituents, viz. débris of blood-cells; red blood-corpuscles; granular matter; exudation cells; tube-casts, fatty, hyaline, and bloody; and, occasionally, amorphous urates or phosphates. Bile-pigment could be detected in some cases, but no bile-acids. In one of the cases it is recorded that hæmin crystals were found in the sediment. We are inclined to doubt the accuracy of the observation; it appears to us that the crystals were more likely to have been ordinary urinary crystals coloured by the colouring matters of the blood present in the urine.

Spleen.—Enlargement of this organ is not so common as is its alteration of colour. In not a few instances the organ was found to be swollen, but in others it was normal in size. Usually its substance is congested and friable, and in some cases soft and easily lacerated. The colour is usually dark, varying in tint from brownish-red to blue.

Stomach and Intestines.—Examination indicates changes which point to the direct action of the arsenical poison. As has already been shown, the stomach is one of the organs by which arsenic is eliminated from the body, and in this regard it would appear as if it were of little consequence by which channel the poison entered the body. By reason of the more or less constant vomiting which ensues after the inhalation of the gas, and of the great strain on the organ, as is evidenced by the bloody vomit in the later stages, the discovery of pathological changes in the stomach might be anticipated. In addition to a

more or less hyperæmic state generally of the mucous membrane, patches of inflammatory action in the greater curvature have been found. Submucous hæmorrhages, in the form of petechiæ, are by no means uncommon. The mucous lining of the intestines shares a similar condition.

Diarrhœa is a very common symptom at some stage of the history of cases. In at least sixteen of the recorded cases was diarrhœa present. In some the stools were thin and dark-coloured, in ten there were bloody stools, while in certain others the stools were dark-coloured but did not contain blood. In isolated cases the bowels were normal or constipated, while in one case only a clay-coloured stool was passed, accompanied by a tubular membranous-looking slough, ragged in appearance, and about four inches in length (Case V.).

The chief pathological changes in the intestines may be summarised as follows: Hyperæmia of mucous membrane; bluish coloration of the same; and petechial hæmorrhages, which are spread more or less extensively over the mucous tract. These petechial hæmorrhages are not limited to the intestinal tract, for they have been found in the pericardium and endocardium. The loss of blood from the bowel, nose, gums, and other parts of the body, as well as the petechial hæmorrhages, indicate fatty changes in the coats of blood-vessels.

Changes in the Blood.—It is only since the hæmolytic action of this gaseous poison on the blood has come to be better understood that much attention has been paid to this fluid during life in cases of poisoning by the gas. In Table IV., Appendix, we have tried to show the results of such examinations. Reference, however, to the facts found in the examined cases demonstrates the following general alterations as prevailing: (*a*) solution of the

blood-colouring matter from the stroma of the corpuscles, and its existence in a dissolved condition in the blood-plasma; (*b*) reduction in the hæmoglobin value; (*c*) alteration in shape and colour of the red corpuscles; and (*d*) considerable reduction in number of corpuscles per cubic millimetre.

The spectrum in the observed cases has been different in each case: in one it was of oxy-hæmoglobin; in a second of mixed oxy-hæmoglobin and met-hæmoglobin; and in a third of reduced hæmoglobin.

Experiments have many times been made *in vitro* to discover the exact effects of the gas upon the blood constituents when the gas is brought directly in contact with the blood.

Rabuteau [1] describes the results of passing a current of the gas through defibrinated blood. He found that almost immediately after the gas had been passed for some time the blood became black as ink. On examination by the spectroscope, the blood gave a spectrum of a broad band between Frauenhofer's lines D and E and the intermediate space, which resembled the spectra of seleniuretted hydrogen and of ammonium sulphide, excepting that the centre of the band was less dense. If the blood were diluted with water, and the gas further passed through the mixture, the above band disappeared, the liquid itself became of a greenish-yellow colour, resembling urine, which did not yield a spectrum. If thereafter a current of oxygen were passed through the solution, little or no change was produced. Rabuteau concluded, therefore, that the gas reduced hæmoglobin, indeed destroyed it, and that the resulting coloured solution was not changed by the action of oxygen. He maintained further that the

[1] *Comptes Rendus de la Société de Biologie*, 1873, p. 153.

gas liberated the iron from the blood, as proved by the formation of Turnbull's blue on addition of ferricyanide of potassium. The pigment, which is liberated into the liquor sanguinis in the above-named circumstances, is peculiar in some respects. It is insoluble in acids, in alkalies, and also in alcohol. By reason of its yellowish colour, it has been called by Kelsch and Kiener "pigment-ochre" or "ochre-pigment." It may be, perhaps, that it is an earlier form of the melanin pigment which is found deposited in the tissues of a patient during life, and found in the liver after death, of persons poisoned by this gas, but it is certain that in this condition it is not identical with melanin. It would appear as if, at first, it was different from its later condition; for if tests for iron be applied in the earlier stage, they prove negative, whereas when applied later the reactions of ferrous iron are obtained, both with ammonium sulphide and with ferro-cyanide of potassium. In this way, perhaps, is the view probably accounted for that one observer, as Rabuteau, declares that the action of the arsenical gas on the blood is to liberate iron, and another that iron is not liberated.

Mann and Clegg[1] repeated these experiments, but passed the gas for varying periods through human blood. After the gas had been passed for about four or five minutes, the blood changed in colour from red to a dirty brown, and showed spectroscopically the additional narrow band of met-hæmoglobin to those of oxy-hæmoglobin. If this blood, so changed, were thereafter exposed to the air at about 60° F., for several hours, the former band disappeared, but the latter bands remained. If, however, the gas were passed through the blood for half an hour, a considerable portion was permanently converted into

[1] *Med. Chron.*, vol. iii. new series, 1875, p. 168.

met-hæmoglobin, which was quite unaffected by after-exposure to the air. The general effect, therefore, of the arsenical gas upon the blood is similar to that of a weak acid, such as boric acid.

Further light has been shed on this subject by the experiments of Joly and Nabias[1] upon animals with this gas. They constructed an apparatus by which a mixture of gases, oxygen, nitrogen, and hydrogen arsenide in varying proportions might be exhibited to animals. Depending upon the percentage amount of the AsH_3 in the gaseous mixture, and the time during which the animals were made to respire it, symptoms of acute or subacute poisoning were produced: the former terminating in the death of the animal at the end of some minutes or hours, the latter after several days. It is noteworthy that it was only in the latter class of cases that hæmoglobinuria was manifested. If the blood of an animal so poisoned were examined, it was found that the serum contained more than one-half of the total hæmoglobin of the blood, whereas if the death were very slow, the dissolved hæmoglobin passed into the serous fluids of the body, pleural, pericardial, and peritoneal, but chiefly into the two first, and also into the urine. It will be observed that in the cases recorded this phenomenon was met with on post-mortem examination in Case XXI. See also Table III., Appendix. These observers also discovered that this was not the only effect of the gas on the blood. They found, in addition, that there was partial transformation of the oxy-hæmoglobin into met-hæmoglobin, an observation which is corroborated by the experiments of others. Under this double influence, then, arterial blood takes on a colour more or less dark, depending on the degree of

[1] *Comptes Rendus*, 1890, vol. cx. p. 626.

intoxication, and is not reddened on after-exposure to the air. By this action, moreover, the respiratory action of the blood is seriously depreciated. For example, Joly and Nabias found that the blood of a dog which before inhalation of the mixture of gas and air absorbed 23 c.c. of oxygen per cent, immediately after inhalation absorbed only 7·8 per cent. This fact, they add, is of importance for diagnostic and medico-legal purposes.

Lucas[1] also made experiments on the blood *in vitro* by exposing it to the action of the gas. He collected in a preservative solution a litre of the blood of a bull, one half of which he left untouched, experimenting only with the other half. This latter half he introduced into a vessel the mouth of which was stoppered with a cork pierced with two holes through which glass tubes were passed for different distances, so that by one tube the gas could be made to pass into and through the blood, and the other to enable the gas to escape from the vessel after it had passed through the blood. The effect was that the superficial layers of blood became black, and the upper part of the vessel became filled with dark-green coloured bubbles to such an amount that they even forced themselves out of the exit tube. The lower layers, however, retained their original red colour. But after agitating the whole together, the mass became of a violet colour, just like what he had seen in the blood of animals upon whom he had experimented by causing them to inhale the gas. On examining this blood microscopically, he found that the red corpuscles were much changed and deformed in shape, whereas in the untreated blood no such change was apparent. On permitting the treated blood to separate into clot and serum, the latter was found to be of a dark-

[1] *Op. cit.*

red colour, to contain a few altered red discs, and to give the spectrum of hæmoglobin, whereas the serum of the untreated blood presented the usual clear straw-yellow colour. Lucas shares the usual view that hydrogen arsenide belongs to the class of poisons to which Ponfick gave the name of cyhæmolytic poisons, and that consequent upon this action the residue formed by the destruction of the red corpuscles accumulates in the different organs, and operates to produce the intense congestion of these organs which is found in necropsies. He thinks that for the most part the colouring matter is eliminated by the urine, but that a certain proportion of it remains in the body, as shown by Ponfick, Lebedeff, and Litten, who are of opinion that it is possible to have hæmoglobinæmia without hæmoglobinuria. Lucas also believes from his observations that some part of this dissolved hæmoglobin is utilised by the liver to form biliary pigments.

From the foregoing experiments, therefore, there cannot remain the least doubt that hydrogen arsenide produces rapidly a profound change in the blood, and it is hardly possible to believe that accompanying this physical destruction of the red corpuscles there is not, at the same time, and probably as the result of that destruction, some change also in its chemical composition. This is indicated by the fact that in experiments which have been made free hydrogen arsenide has not been found in the blood of those who have been exposed to its influence. In one of the cases recorded by Dixon Mann and Clegg,[1] attempts were made by distilling the blood *in vacuo* to discover whether or not the arsenical gas existed in a free state, but without success. The inference is further strengthened by the diminution in the oxygen-absorbing capacity of the

[1] *Op. cit.*

blood after exposure to the gas. Without appearing to be too dogmatic on this point, it seems to us that the chemical change which the gas undergoes takes the form of an oxidation process, and that this probably occurs at the expense of the oxygen of the blood in the conversion of the AsH_3 into As_2O_3, the hydrogen also uniting with the oxygen to form water.

Table IV., Appendix, summarises in the cases recorded: (*a*) the condition of the blood corpuscles; (*b*) the blood spectra; (*c*) the condition of the urine; and (*d*) the state of the bowels: so far as these have been observed and noted.

CHAPTER VI.

SYMPTOMS AND POST-MORTEM APPEARANCES PRODUCED EXPERIMENTALLY UPON ANIMALS.

Lucas,[1] under the head of pathological anatomy in his brochure, gives an account of experiments which he made upon dogs with this gas. The apparatus used was as follows: Into an ordinary hydrogen-generating apparatus containing some zinc and acid they put 8 grammes of arsenious acid. Before adding the acid, the apparatus was connected with a gas-holder filled with water, into which the gas-effluent tube from the hydrogen apparatus was fitted. This precaution was adopted to prevent any of the gas being diffused into the surrounding atmosphere. By the foregoing method they obtained hydrogen containing AsH_3 in considerable proportion, but not pure AsH_3. Since the bulk of accidental poisonings ordinarily occur from the gas in like impure or mixed condition, it was not deemed necessary to have the gas absolutely pure. The box in which the animals were confined during the experiments had a communication with the gas-holder by means of a rubber-tube furnished with a tap. The object of the experiments was to study the lesions of the principal organs produced by the inhalation of the gas, and especially those of the liver and kidneys.

Six dogs in all were the subjects of experiment. Four of

[1] *Op. cit.*

them succumbed within thirty-two hours after exposure to the gas, the fifth died at the end of five days, and the last, which was subjected to the repeated operations of small doses of the gas, was killed at the end of thirty-five days. The first four died of sub-acute poisoning. The symptoms which they exhibited were as follows: Obstinate vomiting of a distressing kind in all; paresis of the hind-quarters in all; hæmoglobinuria in three; and jaundice in two. In the others, death was too rapid for these latter symptoms to have time to develop. Hæmoglobinæmia, however, was found in all the six subjects of experiment.

The following are the leading details of the experiments:—

I. A young dog weighing about 8 kilogrammes was made to respire the gas for *eight* minutes. When it left the experimental box, it was observed that it had already vomited on two occasions, that it was dull and walked with its head down, and that its hind-quarters were enfeebled. It made incessant efforts to vomit, at first rejecting undigested food, and later, stringy, bilious mucous matter. The pulse was regular and numbered 140 per minute. The breathing was short and quickened. Half an hour later, after severe efforts to defecate, it passed with difficulty some drops of a greenish liquid. The breathing became more oppressed, and the animal became cold. Still later, its respirations numbered only ten per minute, the pulse fell to 60, it lay upon its side, and its tongue, bluish in colour, hung out of its mouth. It died five minutes later.

A few minutes before its death it was bled from the saphenous vein. The blood was found to have a dark-violet colour. Microscopically, it showed among the healthy red corpuscles a large number of discs with various

deformities. Some of these were crenated, others were of diverse polyhedric forms, and others appeared to be nucleated. The serum, separated from the clot and diluted with water, showed the spectrum of oxy-hæmoglobin.

Post-Mortem Examination.—In almost all the organs no lesion other than intense congestion was found. The lungs were extremely congested, red, and swollen, they did not crepitate, and their surfaces presented large ecchymotic patches. On section, an abundant rose-coloured mucous liquid exuded. The organs, however, floated freely in water. The heart was filled with clots, and there were two small blackish patches under the endocardium, one on the posterior wall of the left ventricle, the other at the base of the mitral valve. The liver was dark-red in colour. The gall-bladder contained about 10 grammes of bile, which was dark in colour. The spleen was practically normal. The stomach was contracted, very congested, and contained a considerable amount of bilious and mucous liquid. The first part of the intestine was filled with bile, and was also much congested. The kidneys were smooth on the surface, the capsules stripped easily, and on section the organs presented a uniformly red colour. The urinary bladder contained about 20 grammes of normal urine.

Histological Examination.—In the lungs the alveolar epithelial cells were found to be swollen, and some of the cells had become detached from the walls and had fallen into the alveolar cavities. In the interior of the lobules were collected masses of red corpuscles, white corpuscles, and epithelial elements. The vessels were filled with coagulated blood, their walls were thickened, and the capillaries dilated. In the liver, the arteries and veins were found full of blood, and their walls thickened; the biliary channels had thickened walls, the epithelial lining

was swollen and granular, and the nuclei of the cells were much coloured. The hepatic cells were also swollen, their nuclei being very apparent. In some of the sub-hepatic veins some endophlebitis was found. In the kidneys, the glomeruli were normal for the most part, some presented a granular zone more or less extensive, the epithelial cells of the cortical tubules were swollen, their protoplasm cloudy and granular, and their nuclei very apparent but less coloured than normal. The lumen of the tubes was obstructed by granular débris. The vessels were engorged with blood and their walls thickened.

II. A dog weighing 10 kilogrammes respired the gas on two separate occasions with an interval of a quarter of an hour. Vomiting occurred as in the former animal, and its gait was staggering. An hour later its respirations were 33 per minute. The pulse was regular and numbered 110 per minute. There was gradually increasing feebleness of the hind-quarters, and, generally, the animal bore the appearance of being profoundly affected. It was bled at the last, and showed no sensibility whatever during the operation. The blood had like appearances as in the former case. Half an hour later, the respirations had increased to 53 per minute, but the pulse had fallen to 95, though still regular. Its tongue was violet in colour. It died three hours after the experiment.

Post-Mortem Examination.—The lungs were as in the former case. The heart showed only one black patch near the mitral valve. The liver was enlarged and was violet in colour. There was little bile in the gall-bladder. The spleen was very large, very congested, and its tissue very soft. In the stomach, near the pyloric orifice, was a red patch about the size of a two-franc piece. The organ contained a large quantity of bile, as did also the first

part of the intestine. But for being congested the kidneys were fairly normal. The gall-bladder was absolutely empty. Histological examination of liver, lungs, and heart gave practically the same results as in the previous case, but the kidneys were less affected, as only in a few of the glomeruli was any granular zone detected.

III. A dog weighing about 15 kilogrammes respired the gas for *five* minutes. On leaving the experimental chamber it passed some urine of normal appearance which, however, was not collected. The animal looked ill, was sick, and from time to time made efforts to vomit. Its gait was staggering. These were the only symptoms evident to the eye at first glance. Four and a half hours later, it took a meal with apparently good appetite, and it being thought that its symptoms were of a very light character, it was left overnight with the intention of exposing it to the gas on the following day. Next day, however, it was found lying very stricken, having in the interval passed no urine. Fibrillary contractions of the muscles of the shoulder were seen, but there had not been any vomiting. Its respiration was good, as was also its heart's action, its rectal temperature being 36·5° C. The eyes were injected, the sclerotics having a decided icteric coloration. Five hours later it became cold, its temperature now being 36·2° C. It was bled from the saphenous vein, and the blood was collected in an artificial serum composed as follows:—

Distilled Water . . .	800 grammes.
Glycerine	200 „
Sodium Chloride . . .	10 „
„ Sulphate . . .	10 „
Corrosive Sublimate . .	0·5 „

Examination of the blood gave identical results to those already recorded in the first case. The animal died three hours later.

Post-Mortem Examination. — The lungs, heart, and spleen were normal. The liver was very jaundiced and was markedly congested. The gall-bladder was distended by thick bile, very dark in colour, but with no sediment. The kidneys were extremely congested and of a dark-violet colour. On section, they presented a uniform reddish-black colour. The urinary bladder contained 200 grammes of black urine, blood-coloured, and very albuminous. The urine contained no corpuscles, no biliary pigments, no bile-acids, but after dilution with water gave the spectrum of oxy-hæmoglobin. The stomach was full of bile, as was also the first part of the intestine.

Histological Examination.—There was nothing found abnormal in the structure of lungs or heart. In the liver the large biliary channels were dilated and obstructed with bile, their walls were thickened, and the epithelial cells lining their walls showed coloured nuclei. The hepatic cells were large and showed granular deposit. The kidney conditions were much the same as in the previous case, but perhaps more severe. In the tubuli uriniferi the nuclei were imperceptible in the greater number of the epithelial cells. Numerous crystals of an undetermined kind were observed in the cortical substance. These had a rose-colour, were disposed in bundles, but were without any very characteristic crystalline form.

IV. A young, vigorous dog weighing 12 kilogrammes, which had on previous occasions respired the gas for two minutes at a time, was made on this occasion to inhale the gas for four minutes. On coming out of the chamber

it did not appear to have vomited, or, indeed, to have been much disturbed by its exposure; but at the end of five minutes it fell on the floor as if suddenly struck down, in a condition of absolute muscular helplessness. Respiration was at first rapid, then slowed down little by little, the movements of the chest grew less distinct, and then disappeared, although diaphragmatic breathing continued for a little longer. It then became cold, and died at the end of twenty minutes.

At the autopsy the lungs were found to be pale and retracted; the heart contained the usual clots; the urinary bladder was quite empty; and there was nothing noteworthy in the other organs. Owing to an accident, the parts were not histologically examined.

V. A dog weighing 8½ kilogrammes respired the gas for one and a half minutes. Next day it passed blood-coloured urine in abundance, which contained no red discs, but was very albuminous. Nevertheless it did not seem to be ill. On the following day it again respired the gas for one minute, which was followed the day after by the voidance of urine more black in colour than before, and which now contained a large number of misshapen red discs. It also contained abundant urea, as shown by the formation of nitrate of urea on the addition of nitric acid. The following day the dog seemed better. The urine became lighter in colour and gave the reactions for bile-pigments and bile-acids, although jaundice was not apparent externally. The urine, however, still contained red discs and crystals of ammonio-magnesia phosphate.

The same evening it was made to respire the gas for half-a-minute. Next day feebleness of hind-quarters appeared. It refused all food. Albumin and red

corpuscles, together with the ingredients already named, were still present in the urine, but there was no trace of hæmoglobin. The same day it was made to respire the gas for two minutes. It died on the day following.

At the autopsy the heart was found normal, the lungs a little congested, but the liver was icteric, and the gall-bladder full of somewhat thick bile, but sufficiently fluid to flow through the excretory ducts. The stomach and first part of the intestine contained much bile. The kidneys on section were red in colour and congested. The urinary bladder held some drops of urine together with a blackish mass, resembling the marc of coffee, which was found to be composed of altered blood-corpuscles.

Histological Examination.—There was nothing unusual found in tissues of lungs or heart except congestion of vessels. In the liver the large biliary canals contained a certain amount of bile, but they were neither dilated nor obstructed by that secretion. The hepatic cells were swollen and enlarged, and their nuclei much coloured. The condition of kidneys was as in the previous cases.

VI. A dog weighing 8 kilogrammes respired the gas for one minute. Next day, early in the morning, the act was repeated for one and a half minutes. Nothing unusual appeared until the afternoon, when the animal voided urine of a blood-red colour and containing albumin. The day following it seemed ill, had vomited all the food it had taken, and had passed no more urine. Later in the day, however, it voided about 300 grammes, which contained no red discs. Having been put at liberty in the laboratory it disappeared, and was not again seen until two days later, when it was found in the neighbourhood of the building. In the meanwhile it had aborted a fœtus of five months. That night it was found that

the urine was only a little coloured, but contained still some albumin. By next day, the 19th of the month, it was visibly improving, and on the 20th every morbid symptom had disappeared. From the 21st till the 25th it was exposed to the gas daily for half a minute, but no unusual symptom meanwhile developed. From the 25th till the 29th the exposure was increased to one minute daily, and on the latter date the albumin re-appeared in the urine. From the 29th October till the 2nd November the minute period was continued daily, and the albumin increased in amount, and much urea appeared. From the 3rd till the 6th November the daily period of inhalation was increased to two minutes, and the albumin became intense. The inhalations were now definitely stopped. From the 5th till the 7th, the dog seemed almost completely paralysed in its hind-quarters, and it did not pass a drop of urine. By the 9th, however, the urine again became abundant although very albuminous. It was killed on the 18th.

Post-Mortem Examination.—The kidneys were very pale-yellowish in colour, and manifestly had undergone granular fatty degeneration. The capsules peeled easily. Section disclosed a very pale surface, and the cortical substance, which was thin, showed parallel streaks directed perpendicularly to the surface of the organ. The ureters were very large, as thick as the finger, and were even more swollen in some places; their walls were much thickened. On making a cross section, their interior lumen was much constricted by a thickened layer, greyish generally in colour but black in places, which was granular in character, and could easily be broken down by scraping with the finger-nail. Histological examination showed fatty degeneration in many of the liver-cells,

and, in addition to the signs of parenchymatous nephritis, the renal tissues showed the same fatty degeneration.

From these experiments Lucas concluded that the most constant lesion produced by exposure to the gas was epithelial nephritis. During the period of intense hæmoglobinuria, besides, the tubes of the kidney are obstructed by crystals, the precise nature of which is not yet known, but which, according to this observer, are not those of hæmoglobin, because they are not soluble in ether, nor are they urates, because they do not respond to the reaction for murexine. In all probability these crystals are the same as those observed by Litten, and which he believed to be, mistakenly in our view, hæmoglobin crystals.

CHAPTER VII.

DIFFERENTIAL DIAGNOSIS.

From the clinical account of symptoms exhibited in poisoning by hydrogen arsenide, while it may not be a question of very great difficulty to decide as to the cause when the precise circumstances under which they have arisen and developed are fully known, the line of symptoms is not, in several respects, singular to poisoning by this gas, and therefore might be confounded with other diseases and affections. Respecting this form of poisoning, let us recall the following facts regarding the symptoms, viz. (*a*) that in both early and late stages they observe a marked constancy and order of onset; (*b*) that their gravity and lethal character vary within certain limits, depending mostly upon the amount of gas inspired; and (*c*) that they are indicative of a profound constitutional disturbance.

Some observers, more especially Lucas, are inclined to separate these cases of poisoning into two groups because of the prominence of certain symptoms, but this seems to us not to serve any useful purpose. Lucas divided cases into two groups, his differentiating line being the urinary function, viz. (1) that class characterised by serious symptoms and anuria; and (2) that characterised by less severe symptoms and normal diuresis. It is quite clear, however, that for practical purposes such a kind of

cleavage cannot be sustained, since there must be an intermediate class of cases which refuse reasonably to be grouped in either of the foregoing. As matter of fact, since the effects produced are in direct ratio to the intensity of action of the cause, we may expect to find varieties in gravity of symptoms and difference in results.

Before contrasting and comparing the symptoms in this form of poisoning with other conditions, it may be well to keep them before us. They are as follows: (*a*) an indefinable feeling of illness and weakness; (*b*) giddiness; (*c*) faintness; (*d*) pains in head and epigastrium; (*e*) coldness of body and extremities; (*f*) sense of oppression of breathing, with, perhaps, some cyanosis; (*g*) nausea, sickness, and vomiting. These are followed by (*a*) continuous vomiting of bilious matters, and sometimes of blood; (*b*) jaundice, which varies in tint from golden-yellow to mahogany, but which is more usually of a coppery or bronze hue; (*c*) thirst and dryness in mouth and throat; (*d*) pains in loins, sometimes very severe, and constant in all cases; (*e*) hæmoglobinuria, oliguria, and, in serious cases, anuria; (*f*) pain or sense of fulness or distension over liver region; (*g*) hiccough; (*h*) subnormal temperature; and (*i*), accompanying the foregoing, clear intellectivity as a rule, but in certain cases there may be minor degrees of stupor, and, generally before death, unconsciousness or coma.

The diseases and conditions which most closely simulate the above are the following, viz.:—

I. Hæmoglobinuric or Blackwater fever.
II. Paroxysmal hæmoglobinuria.
III. Weil's disease.
IV. Poisoning by potassium chlorate.
V. Poisoning by pyrogallic acid.

I. *Hæmoglobinuric or Blackwater Fever.*—This disease, which is peculiarly a disease of tropical climates, is but very rarely seen in this country. Sir Patrick Manson states that he knows of but five cases which occurred in this country—four in England, and one in Scotland. Its general line of symptoms bears a striking resemblance to that of poisoning by hydrogen arsenide. Rigors, bilious vomiting, jaundice, hæmoglobinuria, oliguria, and occasionally anuria, are its most prominent symptoms; and if we add fever, we complete the picture. Perhaps the existence of hypernormal temperatures is the feature which most differentiates it from poisoning by this gas. At the same time, careful perusal of the recorded cases reveals the fact that in the latter, also, fever has to be noted as occasionally present, although, as a rule, the temperature is either practically normal, or in some cases subnormal.

Blackwater fever being, therefore, a disease notably of tropical climates, there would probably be a history of residence in some such part of the world which would help to clear up the diagnosis. Microscopic examination of the blood of the patient, however, does not always indicate the cause of the origin of the disease. It is true, in some cases, that *plasmodia malariæ* have been found both in the blood and organs of such patients, but the parasitology of the disease—for it is believed by most observers to be due to a parasite—has not yet been worked out to determine its precise character, if, indeed, it be due to a single parasite. There are some, however, who are inclined to attribute its origin to over-dosing with quinine. In the blood, however, very considerable destruction of red corpuscles is found. Sir Patrick Manson, describing the blood of a person suffering from this affection, says, "There did not seem to be a sound

corpuscle in the patient's body; nearly all were misshapen, tailed, buckled, shrivelled, or otherwise deformed; microcytes, megalocytes, and pallid ghost-like corpuscles were present in abundance in every case."

Accompanying the fore-named symptoms are others which contribute to further confusion. These are aching, or even severe pain in the loins, pains over the region of the liver, and pains in the urinary apparatus, the last being accompanied by a strong desire to pass urine, and there may be hiccough.

The urine, when passed, is dark-bloody in colour, sometimes almost black. If it be allowed to stand in a sediment glass, it separates into two distinct layers, the upper being of a clear or dark port-wine colour, the lower of a brownish-grey deposit, amounting to between one-half and one-third the depth of the upper, which deposit on microscopic examination is seen to contain considerable numbers of hyaline and blood tube-casts, much granular material, and epithelium. In addition, there are usually some red discs to be seen. Spectroscopically, the urine gives the spectrum either of hæmoglobin or of met-hæmoglobin.

Jaundice becomes, as in arsenical gas poisoning, an early and prominent symptom. The skin and sclerotics develop a deep saffron colour, which may even be darker than that in some individual cases. In fatal cases, the termination is almost identical with that in poisoning by the gas, viz. either suddenly from syncope or by uræmia.

Post-mortem examination of bodies of victims of this affection shows that the appearances of the kidneys and liver are closely alike to those found in the same organs in gas poisoning. The kidneys are enlarged and hyperæmic, the tubules are blocked with hæmorrhagic

infarcts and blood débris, the cells are filled with pigment, and the capillaries with melanic granular particles. In the liver, which is also enlarged, there is cloudy swelling of the hepatic cells, with deposition of yellow, and, it may be, melanic pigment.

Taking the differential diagnosis of this affection and arsenical gas poisoning from a broad point of view, it would seem, therefore, as if former residence in a tropical climate and fever were the chief features of difference.

II. *Paroxysmal Hæmoglobinuria.*—Attention was first called in this country to this affection by the late Dr. George Harley,[1] although Dessler[2] was probably the first observer of all to describe it fully.

The illness begins with a feeling of cold and shivering, not unlike the cold stage of ague, is succeeded by a rise of temperature, and terminates in the passage of bloody urine. These attacks are intermittent or paroxysmal in their character, hence part of the designation of the affection. The general opinion which seems to prevail concerning it is that, while in the case of some of those affected it is undoubtedly associated with a history of malaria, no such history is obtainable in others. However, whether or not we take the following fact as evidence of its malarial identity, it is, nevertheless, a striking fact that the very same drugs which prove of most benefit in malaria act equally beneficially in the treatment of this affection. Drs. Bristowe and Copeman[3] have recorded a case which may be taken to be typical of the affection, in which the blood of the patient was subjected to careful and exact examination. This man was an omnibus-driver who had contracted syphilis twenty years before, but who

[1] *Med.-Chirurg. Trans.* 1865. [2] Virchow's *Archiv*, 1854.
[3] The *Lancet*, vol. ii., 1889, p. 256 *et seq.*

had never had rheumatism or ague. He had been, and was subject to absolute bloodlessness of the fingers during cold weather and to fits of shivering, followed by the discharge of a porter-coloured urine. He had often been told by his friends that he became jaundiced during the currency of these attacks. An attack came readily upon him even when in hospital on exposure to cold, and thus the precise conditions prior to and succeeding each attack could be closely studied. After such exposure, his temperature was for a short time thereafter subnormal, and then within a few hours later would rise to between 101° F. and 103° F., but again, after the voidance of bloody urine, would fall back to normal.

The average urine passed under those circumstances had the following characteristics, viz. a specific gravity of from 1,020 to 1,025, a colour ranging from dark reddish-brown to a dark-brown sherry, an abundant sediment, acid reaction, and contained hæmoglobin. On examination spectroscopically, it showed the spectrum of acid hæmatin along with that of hæmoglobin, and microscopically, amorphous pigment, white corpuscles, but no red corpuscles. After a variable time the urine resumed its normal appearance. Examination of the blood proved that during an attack there was rapid and marked destruction of red corpuscles. On a certain day before exposure the corpuscles numbered 3,665,000 per cubic millimetre; after exposure, there being the usual rise of temperature and voidance of bloody urine, the number fell to 2,970,000. On other days, prior to the exposure to cold, they numbered 3,612,000, 3,270,000, and 3,433,000 respectively, and after the exposure they fell to 2,930,000, 2,870,000, and 2,984,000 respectively. Moreover, the blood discs did not at all or not readily form rouleaux,

and they were found to have lost more or less their normal shape, some being fused together, and many being decolorised, looking like shadows or phantom corpuscles. The hæmoglobin value, besides, had fallen. In the blood on certain occasions minute crystals of hæmoglobin, amorphous hæmatin, and small colourless crystals resembling the proteid crystals of Charcot were found.

Quite apart from the sallow state of the skin which always follows a considerable loss of blood or blood-colouring matter from the body, distinct icteric tints were observed in this case, as have been also observed in other cases of this affection, but never to the degree prevalent in arsenical gas poisoning. It does not seem clear that the true pathology of this affection has as yet been discovered. It is difficult, indeed, to believe that the mere action of cold should be able to induce such grave changes in the blood-stream as are here demonstrated, notwithstanding that the history of the foregoing case points to this. But in a case observed by us, which after several severe attacks spread over some months ended fatally, no such history as the above could be recorded. In view, moreover, of more recent researches into the cytology and parasitology of the blood, and of the discoveries therein, it would, perhaps, be well to suspend judgment meanwhile regarding the exact cause or causes of this affection.

III. *Weil's Disease.*—More or less closely allied in symptomatology and to the mode of onset and progress of the symptoms of poisoning by this arsenical gas, is the affection denominated as above, of which typical cases present the following history and appearances, viz. a history of shivering, severe headache, aching pains in limbs, great debility, gradual onset of drowsiness and

stupor, increasing even to incoherency of thought, unconsciousness, delirium, coloration of skin ranging from simple duskiness to deep jaundice, pain in stomach and over region of liver, both initially and on pressure, oliguria, melæna, and sometimes diarrhœa. In fatal cases the stupor gradually increases up till time of death. In cases which go on to recovery, the urine increases in quantity and improves in general appearance, the jaundice lightens, and the stupor disappears. Post-mortem examination reveals enlargement of the liver,[1] but no jaundice of liver substance, the gall-bladder empty and collapsed, and the bile-ducts also empty. The kidneys are swollen and hyperæmic, the epithelial cells granular, the tubules filled with exudation, mostly translucent, but in some tubules pigmented and of a dark granular appearance.

IV. *Poisoning by Potassium Chlorate.* — This is relatively of very rare occurrence when we consider its common use as an internal drug or in gargles. Cases have, however, been reported from time to time, and the symptoms are so like in some respects to those produced by the gas in question that careful notice must be given to them. The following two cases may be deemed to be fairly typical.[2]

One was that of a young woman, aged twenty, who took by mistake for Rochelle salts two tablespoonfuls of this salt. About twenty hours thereafter, her symptoms were as follows: She was profoundly prostrated; her temperature was 99° F.; her pulse numbered 36, and her respirations 32 per minute; the body surface was cyanotic; the breathing rapid but not laboured; the pulse rapid though not feeble. She had vomited freely,

[1] The *Lancet*, vol. ii., 1888, p. 42.
[2] *New York Med. Record*, July 21, 1888.

and was still vomiting after admission into hospital. Two hours after admission the temperature had risen to 104° F. Three dark-brown motions had been passed, and dark-coloured urine was voided involuntarily. The urine contained many blood-cells, large masses of altered hæmoglobin, and much albumin. Next day there was a slight improvement, which, however, soon passed away. Her skin, conjunctivæ, and lips showed an extraordinary colour, something between cyanosis in an anæmic person and a sepia or brown-chocolate tint. She died thirty-seven hours after the poison had been taken, having been in a state of stupor up till her death.

The necropsy showed that in addition to the chocolate colour of the body there was a slight icteric tinge. The blood of all the great vessels was liquid and of a very dark chocolate colour. The heart was soft and flabby; the lungs were normal, but on section were very brown in colour; the spleen was large, firm, and of a very distinct chocolate colour, and the kidneys were large, containing chocolate-coloured blood, the capsules being non-adherent. The bladder contained three ounces of urine of a dark-brown colour. Spectroscopic examination of the blood showed distinctly the spectrum of met-hæmoglobin. Microscopic examination of the tissues of various organs revealed, among others, a very extensive fatty degeneration of the heart muscle, and that the tubules of the kidney were filled to distension with broken-down corpuscles and blood-pigment.

The second case was that of a man of the age of fifty-three years, who had taken, for a couple of years at least, this drug very freely for a chronic throat affection. The immediate cause of his condition was an overdose of the chlorate. His symptoms were practically those just

described. He became anæmic, anuric, and jaundiced, and he died comatose. At the autopsy, the heart and kidneys were in the conditions above described, the bladder contained urine which was almost black in colour, and the gall-bladder was full of thick and very dark-green bile. The spleen was six times larger than normal, and of a very dark chocolate colour, the kidneys also sharing this colour. Other cases will be found under the following references.[1]

V. *Poisoning by Pyrogallic Acid.*—This acid, like the previous salt, when swallowed or absorbed into the body, produces symptoms very much alike to those from arseniuretted hydrogen. They do not usually come on, however, until from one to fifteen days have elapsed, depending upon whether the acid has been swallowed or has been absorbed. They consist of nausea, vomiting, diarrhœa, great weakness, hæmoglobinuria, bloodlessness, and great difficulty of breathing. The acid, like the salt, acts as a hæmolytic poison, setting free the corpuscular hæmoglobin into the blood-plasma, hence the hæmoglobinuria. It will be remembered that in gas analysis pyrogallate of potassium is used as an absorbent of oxygen. When, therefore, the acid is taken into the body, it is likely to unite with alkalies to form salts, and thus produce in a limited way the same effects upon the tissues and blood. Used by those who practise the photographic art, and thus being comparatively easily procured, it is being more frequently employed for suicidal purposes.

Reviewing, then, the conditions and affections which simulate by their symptoms poisoning by the arsenical gas, it will be apparent that care and discrimination must

[1] Jacob, *Berliner klin. Wochenschr.* 1897 ; *Brit. Med. Journ.* vol. i., 1907, p. 116.

be employed in the differential diagnosis of the last-named. If such be used, however, and if, in addition, the inquirer have some knowledge of chemistry, the circumstances attendant upon the sudden illness will ordinarily assist in arriving at an accurate conclusion as between the operation of diseases and the effects of poisoning. At the same time it has to be borne in mind that poisoning by the arsenical gas sometimes arises in the most unexpected circumstances.

CHAPTER VIII.

TREATMENT IN ARSENIURETTED HYDROGEN POISONING.

THERE is probably no class of cases of poisoning more difficult to treat satisfactorily than those in which the poison has entered the body in the gaseous form, because the poison is at once absorbed into the blood, through which it more or less seriously interferes with the integrity of the functions of all of the various important organs. This is particularly true of such gases as carbon monoxide, phosphuretted hydrogen, seleniuretted hydrogen, the gas at present under consideration, and some others, as sulphuretted hydrogen, which either form compounds with the hæmoglobin, or exercise a direct destructive action on the blood corpuscles. No matter the precise effect they produce, however, the general effect is to cripple in a greater or lesser degree the capacity of the red corpuscles to convey oxygen to the tissues; consequently it becomes a most difficult problem to devise measures to counteract such action, and to tide the patient over the period of critical illness. So long as the integrity of the red corpuscles is not involved, there is some chance in being able to do this, because in the poisonous action resulting, for example, from inhalation of carbon dioxide or other carbon gases except the monoxide, time will quickly tell whether or not the efforts employed are likely to prove

availing. But the case is entirely different when the corpuscles are themselves attacked by the gas, when they are broken-down, altered in shape, and, in short, destroyed in large part, and particularly when the hæmoglobin is dissolved out of the corpuscular plasma into the liquor sanguinis; for then we have to deal not only with an imminent menace to life, but we are confronted with a series of difficulties even after the patient has survived the primary effects of the profound shock to the system, difficulties, besides, which are experienced from interference with the physiological functions of important organs, and also from histological changes which the tissues of some of these organs undergo. It is not difficult to comprehend why the functional integrity of so many organs is involved when we remember that the nutritive fluid which is conveyed to them is in such a disorganised condition, and is thus incapable of supplying them with properly oxygenated blood, not to speak of the action of the toxic substance which is also held therein.

If we consider for a moment the symptoms which are exhibited in poisoning by this arsenical gas, the foregoing statements will be fully borne out. The pains in the head, the sense of profound depression, the incapacity to think, and the sleeplessness all point to serious disturbance in the brain circulation; the nausea, sickness, and vomiting, which are continuous and severe, to distinct irritant action on the stomach; the oppression in breathing and the cyanosis, to interference with the oxygenation of the blood; the weakness in the lower limbs and the staggering gait, to functional disturbance of the spinal cord; and the appearance of jaundice, to functional mischief in the liver, due to the large import to the organ of abnormal blood. Moreover, the onset of bloody urine, the

partial, and, it may even be, the total suppression of urine, together with its unusual constituents, indicate but too truly that the kidneys are experiencing not only great difficulty in functioning, but also that this is accompanied by structural changes in the organs themselves. As has already been incidentally remarked, it is somewhat remarkable that, in this gaseous form of arsenical poisoning, the very organs which are mainly attacked when the poison has been ingested or absorbed by some other channel should also be elected for special injury; indeed, there can be little doubt that arsenic, no matter the form or manner in which it has been administered or exhibited, exercises a selective action upon the stomach and kidneys, more especially perhaps upon the latter organs, by reason of their being the principal emunctories of the poison from the body.

The treatment of arsenical gas poisoning must resolve itself into three main lines, viz. (*a*) to provide in some artificial manner oxygen to the blood which, by reason of its disorganised state, is incapable of being sufficiently aerated in the lungs, and is therefore unable to supply to the various organs the needed oxygenated blood; (*b*) to enable the body to rid itself of the poison which it contains, and which it is trying to effect mainly by the kidneys; and (*c*) to treat urgent symptoms, give comfort to the patient by affording sleep, and, if possible, to allay the stomach irritation.

Some are inclined to add to the above the administration of certain neutralising drugs, such as magnesia in some form or other. But this, in our opinion, would be futile if the patient is constantly vomiting, as he is likely to be, and would only tend toward increased discomfort. But even supposing that the patient were able to retain

such medicines, it is impossible to expect that they could in any effective way be operative upon a poison which is no more present in the stomach than in any other organ of the body; hence they cannot exercise any essential antidotal effect.

The urgent requirement in such cases, particularly where the case is severe, is the administration of oxygen, and what promises to be the most effective method of administering it is by inhalation. But this mode of supplying the system with oxygen is not quite so effective as at first sight it would appear to be, for it is but reasonable to suppose that if the blood, on account of its disorganised state, is incapable of being oxygenated in the natural way, it will equally be incapable of utilising it if presented artificially in more abundant form. Notwithstanding these objections, however, it is undoubtedly the remedy which ought to be offered to a patient in this condition, in the hope that some benefit may result, and all the more because all the red corpuscles are not destroyed, and are therefore still able to exercise their duty as oxygen-carriers. From the history of the cases which were treated by oxygen inhalation, and by reason of the apparent benefit which the patients experienced, we are encouraged to expect some measure of relief, if even temporary, from its use; in any case, it appears to be the best remedy at our disposal to overcome the primary effects of the poison. Where oxygen may not readily be procured there may be substituted some medicinal agent which contains available oxygen, such as hydrogen peroxide, in small but frequently repeated doses.

To enable the system to rid itself of the poison, that end is likely to be best achieved by assisting the skin and kidneys to act as freely as possible, the former by the use

of diluent diuretic drinks, and the latter by the use of hot packs or baths. There can be no doubt of the efficacy of hot or vapour baths in setting up free perspiration, but should the patient be too weak to be lifted with safety into a bath, hot wet packs may be applied in bed. The establishment of free action of the skin affords much relief to such patients, and it has the effect of warding off the onset of uræmic complications, which, in certain cases, seem to have hastened the end. It is necessary during the treatment, after some recovery from the primary effects has been attained, to keep strictly in mind the tendency to fatty degeneration which the heart muscle undergoes. Any sudden exertion on the part of the patient, or even the lifting of the patient from his bed, may be followed by serious consequences, such as heart failure. In some of the recorded cases, heart failure seems to have caused death some days after the primary effects had been survived.

The last line of treatment must be determined by the circumstances of each individual case, and, therefore, need not be considered in detail. And the same is true of the adequate alimentation of the patient throughout the currency of the attack; indeed, by the administration of stimulants and small quantities of non-nitrogenous foods at short intervals, after the skin has commenced to show signs of more active function and the stomach to retain food stuffs, not a little may be done to expedite recovery.

CHAPTER IX.

PREVENTIVE MEASURES.

As has already been incidentally remarked, if care were exercised to test the purity of reagents necessary for the generation of the hydrogen used in physiological experiments, poisoning by this gas would never occur under such circumstances. It is only too clear, however, that in the cases recorded in this connection, either suspicion was not entertained respecting the likely contamination or impurity with arsenic of the chemicals employed, or that the users were lulled into a sense of false security by these chemicals having been purchased as pure, since in no instance do the reagents seem to have been tested as to purity. It should be a standing rule, however, when hydrogen is required for laboratory physiological purposes, that the reagents should be submitted to a preliminary trial with respect to their possible arsenical content. There is no hardship or sacrifice involved in this for scientific persons, and, moreover, it would secure absolute safety.

Circumstances are different, however, with respect to trade processes. It would be impracticable to expect, as a rule, in chemical works where products are manufactured on a commercial scale, that the chemicals employed should be absolutely pure and arsenic-free; at the same time, workers therein have a right to expect that provisions shall be made for their reasonable protection, especially

when it is known that they are engaged in working with and among arseniferous materials. Such occupations must be looked upon as dangerous, and, therefore, such necessary precautions should be enforced as the Legislature is entitled to exact.

In the Report of the Departmental Committee on Compensation for Industrial Diseases, 1907,[1] before which Committee we were invited to give evidence, the Commissioners say "it is unnecessary to add this form of poisoning to the list, as it is already included under the heading of 'Arsenic Poisoning or its Sequelæ.' As the symptoms described, however, differ so markedly from the cutaneous and gastric symptoms of arsenic poisoning, as ordinarily understood, we are glad to have the opportunity of calling attention to the point."

What provisions ought to be made to prevent the occurrence of poisoning by this deadly gas? From a review of the circumstances of the cases hereinafter described, it will be found that in the bulk of them the operations which gave rise to attacks were being commonly conducted in confined spaces, or under conditions in which the evolved gas was impeded in its movement. In view of these facts, therefore, the preventive measures generally must consist of arrangements whereby the noxious gases evolved may be removed from the place of generation as rapidly as possible, in order by free dilution with the air that they may be rendered relatively as innocuous as possible. It is obvious that any provision in the way of muzzle-wearing on the part of employees would be of little actual practical value. Generally speaking, therefore, in all such works ventilating arrangements must be provided for the purpose of drawing away the fumes into a flue, if

[1] p. 5.

possible. It would, indeed, be better in every case if, before passing the gases into the flue, they should be made to pass through the furnace. Particularly ought this to be insisted upon in works in which enormous quantities of hydrochloric or sulphuric acid are used for dissolving metals, such as iron or zinc, to manufacture zinc chloride or iron sulphate. We agree fully with the views expressed by Dixon Mann and Clegg,[1] where they say "it ought to be a standing rule at all works where zinc is dissolved on a large scale in sulphuric or hydrochloric acid, or where any similar operations are performed in which hydrogen is largely evolved from crude materials, that the process should be carried out in a closed vat, furnished with a sufficiently wide earthenware tube, so as to conduct the gases evolved directly into the tall chimney of the works. In this way, dangerous fumes are carried away by the powerful upcast of the shaft even when it is necessary to open the trap-door in the cover of the vat; the workmen are thus enabled to fulfil their duties without incurring any risk." Ordinarily such ventilation by extraction can be secured where there are a furnace and a flue, but where such operations have to be conducted in a building without a flue, or at some distance from one, ventilation by a fan, actuated by electrical, gas, or water motor, could easily be substituted. It ought to be borne in mind, besides, that in such operations it is not enough to secure that they are performed in the open air as far as possible, because, as will be shown in the Accrington cases (p. 165), the arsenical gas, being heavier than air, is apt in still, warm weather, and especially owing to the absence of movement of air, to fall earthwards and to be irregularly distributed or dispersed over unlikely as well

[1] *Op. cit.*

as likely areas. It is necessary, in short, that the scheme of ventilation for removal of gases, whatever it be, should operate directly upon the gas as it is evolved from the vat or retort in which the chemical action is proceeding. In Case XXXIII., in which the zinc was being dissolved by crude hydrochloric acid, arrangements existed in the works whereby the acid was poured down a trough entering into a covered cistern, and provisions likewise existed in connection therewith for carrying away the generated gases to the works chimney by means of a draught apparatus. But on the occasion in which the man was poisoned, he himself had entirely neglected to avail himself of these arrangements. While it is impossible, therefore, to suggest or devise measures of this kind which would be applicable to every work, it will probably be sufficient to establish the principle that in every work such essential measures ought to be instituted as will secure the efficient carrying away of the gases from the point of generation.

In certain trade processes in which fatal issues have occurred, the gaseous poison did not exist *in esse* but only *in posse*. In the Wolverhampton cases, and in those we ourselves record, the gas was generated by the action of the workmen themselves; action, however, which was not only reasonable since it was usual and unavoidable under ordinary circumstances, but which proved to be entirely inapplicable under the peculiar conditions. In the former case, it will be seen that in a large boiler used as a mortar, in which paddle-arms were rotated by machinery, zinc-skimmings were being treated by water from an adjacent canal, the water of which had an acid reaction; that the machinery became jammed by the material, and that the first workman entered the boiler to disengage the jammed material by means of an iron crowbar. In the latter

cases the workmen descended by means of a man-hole into a Welldon retort to clear out the débris which had collected on the floor of the retort after three weeks' continuous working in the generation of chlorine, the implements used for the purpose being an ordinary iron shovel and a zinc-galvanised iron pail. While it is likely in the former case, by reason of the acidity of the canal water, that a certain amount of arseniuretted gas was already present in the atmosphere of the boiler at the time the workman entered, there cannot be the least doubt that by his use of the iron crow-bar he generated sufficiently more gas to produce poisoning. In the latter cases, none of this gas existed in the atmosphere of the retort at the time of entrance of the first workman, but it began to be evolved the moment the workman commenced to shovel the acid débris with his iron shovel into the zinc pail; and, bending over his work as he had to do, besides working in a confined space devoid of any distinct air-movement, the amount of gas generated was sufficient to cause rapid and marked poisonous effects almost immediately, from which he ultimately died. Case XLVII. is a case in many respects similar to the foregoing. In such contingencies as these, while active free ventilation would probably have prevented both accidents, it is evident from the known chemical action which takes place between iron and zinc and either hydrochloric or sulphuric acid in presence of arsenic, that if implements other than those of iron and zinc, as, for example, wood, had been used, the arsenical gas would not have been generated, and the toxic effects would not have been produced; hence the two preventives, viz. active ventilation and the use of wooden implements, are calculated in the future to protect from risk workmen under such or similar conditions.

Dr. Robertson, chemist at Waltham Abbey, has reported (1904) certain experiments conducted by him for the purpose of freeing hydrogen used in lead-burning from arseniuretted hydrogen. The danger arises when the hydrogen is evolved from zinc and sulphuric acid, either or both of which contain arsenic. He finds from experimentation that the danger may be entirely prevented by passing the gas through an efficient gas-washing apparatus or scrubber containing potassium permanganate in solution.[1]

With special reference to ballooning and the operations connected with the inflation and deflation of balloons, probably no writer has devoted so much attention to the preventive measures connected therewith as Maljean.[2] The measures which he recommends divide themselves into two classes, viz. (*a*) general, and (*b*) particular.

Of the former is the use of pure hydrogen, and, failing that, better purification of the gas produced by the use of more efficient absorbents or of destructive reagents, and of the latter, more care in the operation of filling and emptying of the balloons on the part of those so employed, particularly with reference to keeping clear of the filling or deflating parts, and especially the cessation of the habit of sniffing the afferent gas-pipe to discover the arrival of the gas, together with certain modifications of the official instructions contained in the regulations for aeronauts relative to inflating and deflating balloons.

Up till recently (and even largely at present) supplies of hydrogen were exclusively obtained by the methods described in a previous chapter. Maljean, like many others, has realised that the ideal method of production

[1] Dr. Robertson, *Report*, 1904.

[2] *Arch. de médecine et de pharm. militaires*, 1900, vol. xxxv. pp. 82-102.

would be the electrolytic decomposition of water. Such a method has been invented, but whether the increased cost of production over the older method will not be more or less prohibitive, and is likely, therefore, to retard its adoption, is a question for the future to determine. In any case, it can only have a limited use. Till that time, however, when the electrolytic method comes to be more generally adopted, he suggests the use in the circulatory apparatus of such substances as copper sulphate and mercuric chloride, which will decompose the arsenical gas, and, by forming new compounds with its arsenical content, render its passage with the hydrogen impossible. As an alternative, he thinks the sulphuric acid used should be made from sublimed sulphur and not from arsenical pyrites in order to minimise the risks, if not, indeed, to prevent them.

There can be no doubt, as he and others have pointed out, from accidents which have already happened, that so long as the present method of making hydrogen from arseniferous materials continues, those who follow the official instructions contained in the regulations for aeronauts will be exposed to considerable risks of poisoning. He draws special attention to the risks to which civilians are exposed during the bringing to earth of a balloon, and, afterwards, during its deflation, if they are not forewarned against placing themselves within the range of inhalation of the escaping gas. Not infrequently, a balloon comes to earth in an open field in the country, and persons are soon attracted through curiosity to the spot owing to the occurrence of this somewhat unusual experience. Such persons are ordinarily very willing to render any help they can give to the aeronauts. In the army official instructions to balloonists the following is to be found: "The aeronaut

places at the [orifice of the balloon] three or four willing persons, *recommending them not to be disquieted by the odour of the escaping gas, and not to leave their posts: he proceeds in the same way at the appendix.*" [1]

Since persons placed in the above positions are bound to be within the range of leaks and escapes of gas, they are liable to suffer from the effects of the inhalation of the impure gas. At least one fatal case of a willing helper falls to be recorded. Oulmont relates the case of a peasant who, while assisting to bring a balloon to earth, respired the gas which escaped from the valve, and died from the effects of the arsenical gas contained. Maljean recommends, therefore, that the instruction above quoted should be altered so as to contain a warning of the risks to which such persons are exposing themselves. In short, he advises that aeronauts and assistants, military or civil, should be forewarned of the possible risks, and to keep clear of leaks and escapes of gas from afferent pipes or balloon valves, and especially of the dangers attendant upon the common habit of sniffing the former. He points out at the same time that the act of compression at 120 atmospheres of the gas in steel cylinders makes the contained gas less dangerous in respect that the compression tends to decompose the arsenical gas.

[1] *Instruction pratique sur les aérostats militaires*, Paris, 1887.

CHAPTER X.

WALL-PAPERS AND ARSENICAL POISONING.

It has been for a long time a well-established fact that persons who lived for any lengthened consecutive periods in rooms, the walls of which were covered with decorative coloured papers which contained arsenical pigments, were liable to be seized with symptoms of ill-health. Gmelin was the first to draw attention to the relationship between these wall-coverings and the development of the symptoms. He gave particulars of the case of two married persons who, sleeping in a bedroom the walls of which were covered with a green wall-paper, developed unexpected symptoms. The husband awoke each morning with intense headache, dryness of the mouth, and a feeling of general tiredness, which gradually disappeared during the day, only, however, to return the next morning. The wife developed an irritating cough. When the true cause was suspected, and after vacating the room, the symptoms disappeared almost at once. Basedow, also, drew attention to the same facts, and instanced cases in which such symptoms as emaciation, general weakness, especially in the lower limbs, and diarrhœa developed in individuals who lived in apartments decorated with green wall-papers. Two of the cases falling within his observations are of peculiar interest. The first was that of a woman who developed pains throughout her body to such an extent

that for the best part of three years she became practically bed-ridden because of the symptoms which indicated some lesion of the spinal cord. When, however, she changed her abode, the symptoms disappeared, and she was cured spontaneously and quickly. The second was that of a young married lady who suffered from symptoms of anæsthesia referable to the spinal cord. Becoming more and more feeble, she left to spend the summer in the country, when she recovered her health and became pregnant. Returning home, however, the symptoms returned, and she aborted. She recovered rapidly when the true cause of her illness was discovered. Others have recorded like cases.

The symptoms to which the above circumstances are apt to give rise are as follow, viz. coryza and conjunctivitis, a red or silvery-coated tongue, gradual loss of flesh, gastro-intestinal catarrh, indicated by gastric irritability and diarrhœa, and certain not very well-defined nervous symptoms. Most of the cases of poisoning happening under the above circumstances have been associated with wall-papers of a green colour. Such colours are produced by the use of Scheele's green and Schweinfurth's green. We reproduce from our text-book [1] an illustration of a piece of flock wall-paper, dull-green in colour, which measures 23·5 centimetres in length and 15 centimetres in breadth (Fig. 1). From a disc of this, measuring 11·5 centimetres in diameter, crystals of arsenic in the form of arsenious acid were obtained on analysis. The crystals enclosed within the disc were obtained by Reinsch's process, were drawn by the camera lucida, and are magnified exactly 100 diameters.

[1] *Text-book of Forensic Medicine, Toxicology, and Public Health*, 1902, p. 406.

While such wall-papers are not now so much manufactured as formerly, it is believed that they are not

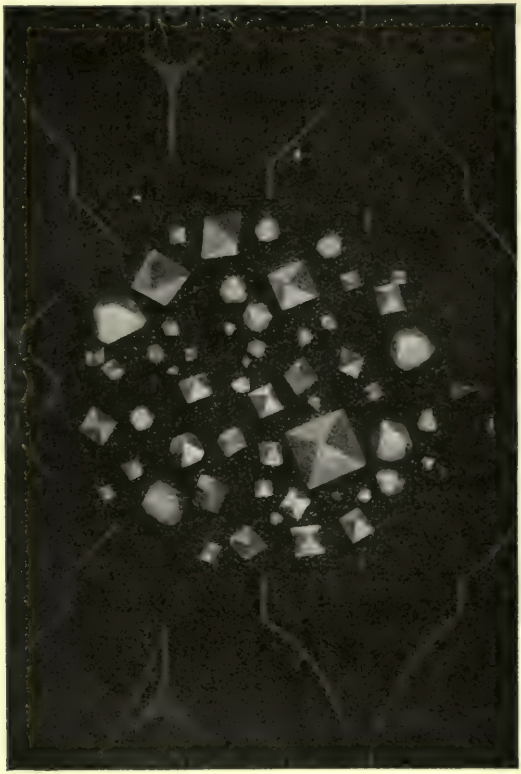

FIG. 1.—This figure represents a piece of dark-green flock wall-paper measuring 23·5 centimetres in length and 15 centimetres in breadth. From a disc of the paper measuring 11·5 centimetres in diameter, the amount of arsenic present was estimated. The crystals of arsenious oxide enclosed in the disc were obtained by Reinsch's process, were drawn by the aid of the camera lucida, and are magnified exactly 100 diameters. (Author.)

wholly excluded from the market. Besides, wall-papers containing arsenical pigments of light colours are not

unknown. Therefore because such wall coverings are not present in rooms inhabited by persons who develop the above train of symptoms, the absence of green colour must not be permitted to lead the observer away from the true clue; indeed, the observer should not rest content until analysis of the wall-paper has been made.

Basedow narrates as one of his cases that of an entire family living under the influence of a room wall-papered with a covering tinted with an arsenical pigment, all of whom suffered from a similar train of symptoms. By reference to Case XIX. in the series of cases embraced in these pages (p. 129), it will be seen that several children of a family were attacked similarly. But it ought to be noted of this family outbreak that there was one symptom, common to them all, which is not noted as having characterised Basedow's family outbreak, viz. jaundice. This jaundice seems, indeed, to have been the most prominent symptom, and it is a sign of some importance as indicating the form in which the arsenic was exhibited in the atmosphere breathed by the children. Probably icterus is the most outstanding differential sign between the action of arsenic exhibited in the form of arsenious acid and exhibited as arseniuretted hydrogen. Indeed, on this point Lucas (*op. cit.* p. 19) goes the length of declaring that jaundice is the chief sign by which poisoning by this arsenical gas may be differentiated from that by arsenious oxide. In this opinion we are inclined to share.

The causal relationship of arseniferous wall-papers to the train of symptoms above enumerated is now so well founded that the matter need not be discussed further.

Differences of opinion, however, have arisen from time to time as to the exact manner in which the arsenic is

disengaged from such papers, and also as to the precise chemical composition of the liberated material. Some have entertained the view that the pigment as it existed in the paper was merely disengaged by attrition, and that the fine product thrown into the room atmosphere was thus inhaled by the occupants; others have affirmed the belief that the arsenic is volatilised by heat in the upper levels of the apartment and is disengaged in the form of arsenious oxide; and others, again, have been forced to the conclusion that the arsenic is liberated in the form of a gaseous compound. While it cannot, perhaps, be asserted with certainty that attrition alone is not a probable mode of disengaging the poison, the results of modern research have made it abundantly clear that the cause in the large percentage of cases is very different. It has been proved beyond doubt that microscopic organisms or moulds are not only capable of growing and thriving in the adhesive starch-paste by which the wall-papers are hung, but that they are also capable of maintaining an active existence in arsenical media, in which during their growth they split up the arsenic and liberate it in the form of a volatile or gaseous substance. At an early stage of the investigation, it was believed that this gaseous form was arseniuretted hydrogen, but later researches have shown that it is not so composed. It may now be taken for certain, therefore, that this gaseous or volatile arsenical compound liberated by these moulds is the source of the poisonous consequences.

There has been a great and fruitful investigation in this field by many observers. Among these may be named Bujwid,[1] Morpurgo and Brunner,[2] Gosio,[3] Abel and

[1] *L'Union Pharmaceutique*, vol. xvi. p. 293.
[2] *Oesterr. Apoth.-Zeitung*, i. 167.
[3] *L'Orosi*, 1900, vol. xxiii. pp. 361-377; *Berichte*, 1897, 30, 1024.

Buttenberg,[1] Biginelli,[2] Abba,[3] Selmi,[4] Gigliotti,[5] Maasen,[6] and others.

The microscopic moulds or fungi which have been found to exercise this liberating action are Penicillium, Mucor, and Aspergillus. Their development is very little, if at all, hindered or retarded by the presence of arsenic in the medium which affords them food for their growth. Of over forty different moulds with which definite experiments have been made, it has been found that at least ten of these are not only capable of living and growing freely in arsenicated media, but that they are also able to decompose arsenical compounds, and to form gaseous or volatile compounds therefrom. Of these ten, *Penicillium brevicaule* was found to give the most marked transforming results. Biginelli found that on growing pure cultures of this mould in presence of sodium arsenite rapid decomposition of this sodium salt took place and a gaseous substance was evolved, which, when passed into a hydrochloric acid solution of mercuric chloride, caused colourless tabular, triclinic crystals to separate out which had the following composition, viz. $AsHEt_2 + 2HgCl_2$; or, $AsHEt_2$, $AsHEt_2 + 4HgCl_2$. These, on standing exposed to the air, gave off an odour of garlic, and became darkened in colour. Further, if the gas was passed into a solution of mercuric nitrate, an infusible, insoluble, yellow amorphous powder was formed, which had the composition of $AsHEt_2 2HgNO_3$. From these and other results,

[1] *Zeit. Hyg.* 1899, vol. xxxii. pp. 449-490.
[2] *Atti Real Accad. Lincei.* 1900, vol. ix. ii. 210-214, and 242-249.
[3] *Centrl. Bakt.* Par. ii. 4, 806.
[4] *Berichte der deutschen chemischen Ges.* 7, 1642.
[5] *Ibid.* 14, 2295.
[6] *Arb. Kais. Gesellsch.* A. 1902, 18, 475-489. *Vide* also Scholtz, *Berl. klin. Woch.* xxxvi. pp. 913-915; Marpmann, *Pharm. Centr.* Halle, vol. liii. 666-672.

Biginelli reached the conclusion that the gas which is evolved from arsenical wall-paper, and which gives rise to the symptoms of poisoning, is *di-ethyl-arsine.*

It will be apparent, therefore, that while we are not strictly justified, from the chemical point of view, in including cases of arsenical poisoning which arise from arsenical wall-papers under the head of poisoning by arseniuretted hydrogen, the relation of that gas to di-ethyl-arsine is sufficiently close to justify their inclusion in our list of cases.

So definite and so conclusive is the reaction which takes place by the growth of *P. brevicaule* in suitable media to which have been added arsenical compounds that Gosio has initiated a test, known now by his name, or by that of Abba, whereby this action is utilised to detect in various substances minute amounts of arsenic. Scholtz affirms the value of this test in the detection of arsenic in skin perspiration, hairs, urine, etc., and declares the process to be much more delicate than that of Marsh, stating that amounts of arsenic of $\frac{1}{200}$th to $\frac{1}{5000}$th of a milligramme may thus be detected. The test has also been employed for the purpose of demonstrating the presence of arsenic in natural waters, coloured fabrics, beer, sugar, and other materials, with satisfactory results. The food medium which is used for the growth of the mould is sterilised bread crumbs, to which the sterilised substance to be tested is added after the medium is inoculated with the mould.

The value of the test chiefly, if not, indeed, entirely, depends upon the detection by the sense of smell of the observer of the garlicky or alliaceous odour which is evolved when arseniuretted gas is present. It is so far, therefore, dependent upon the acuteness of the olfactory sense of the

individual observer, in which respect it is not completely satisfactory. Doubtless, however, the gas may be chemically demonstrated by utilising along with the foregoing procedure Gutzeit's test, in such a manner that its presence may be made visually apparent by the yellow stain which forms upon the spot of mercuric chloride on the test paper.

Moreover, it would be unwise to depend upon the test of smell alone as an incontestable sign of the presence of the arsenical gas, because other chemical substances which are capable of being generated in the same precise way have also this garlicky odour. For example, if a soluble salt of tellurium be substituted for an arsenical salt in the mould-tube, a gas, telliuretted hydrogen, will be given off which has a distinctly garlicky odour, not to be distinguished by the sense of smell from that of the arsenical gas. This has been pointed out by several observers. Maasen (*op. cit.*) has shown that not only the soluble compounds of tellurium but also the soluble salts of selenium are capable of being dissociated, with formation of volatile substances, by *P. brevicaule*, that the volatile substance of the former, like that of arsenic, has an alliaceous odour, while that of the latter has a distinct fæcal odour, probably of the nature of, or allied to, skatol or mercaptan. He shows, however, that while the sulphides and insoluble salts of tellurium and selenium are not attacked by *P. brevicaule*, or at most only very limitedly and after a long time, those of arsenic are freely and rapidly decomposed. This serves as a means of differentiation of these chemical substances. Further, Maasen has found that, by passing the hydrogen gases of tellurium and selenium through solutions of the same composition as those used by Biginelli for hydrogen arsenide, the products formed were of similar

composition as respects their character: that is to say, ethyl or methyl derivatives of these elements are formed depending on the source of their production. Rosenheim [1] has also pointed out that pure tellurium and selenium, unlike arsenic, are not attacked by this mould, and Maasen, that the compounds of these non-metals are capable of being attacked by several moulds which do not act upon arsenic. Such behaviour affords a clue to a method, when more fully investigated, of differentiating these substances from each other.

Rosenheim in an article "Concerning the Influence of Selenium on certain Tests for Arsenic" [2] has pointed out the effects of that substance on the recovery of arsenic by certain tests commonly employed for that purpose. The importance of a knowledge of this inhibiting effect of the former on the latter is all the greater in respect that selenium and arsenic may co-exist in the same material. During the Manchester beer-poisoning outbreak, he and Tunnicliffe [3] showed that selenium compounds were present in the beer as well as arsenic, and they were inclined to attribute the evil effects which were produced more to these than to the arsenic. He shows by experiment that selenium compounds when present with arsenic exhibit a marked inhibitory effect on the magnitude or extent of formation of the arsenical mirror in Marsh's process, and on the deposit upon the copper foil in Reinsch's process. To these, however, we shall return in our consideration of the methods of analysis for the detection of small amounts of arsenic in inorganic and organic substances.

[1] *Journ. Chem. Soc.* 1902, P. ii. p. 138.
[2] *Chem. News*, 1901, vol. lxxxiii. p. 277.
[3] The *Lancet*, Feb. 2, 9, and March 30, 1901.

In the Annual Report of Inspector of Factories for 1900, an investigation was reported by the Factory Department of the Home Office regarding wall-papers. The results were to the general effect that British-made papers might be deemed to be practically arsenic-free, if infinitesimal amounts are left out of count, and that bronze colour contains relatively more arsenic than others.

In 1904 the Department of Agriculture of the United States[1] published a report which contains the results of investigations into (1) cases of poisoning by arsenical wall-papers and fabrics, (2) the arsenical ingredients of those sold in America, and (3) the laws governing the sale of these. Among other valuable information, it is reported that the State Legislature of Massachusetts enacted in 1900 that in wall-papers the amount of contained arsenic must be limited to 0·10 grain per square yard. Of 537 samples of wall-papers analysed, four were found to contain more than the above limit. Two of these four samples were imported from England. Five samples contained between 0·0077 and 0·10 grain per square yard, and 90 per cent of the above total samples less than 0·046 grain per square yard.

[1] Bulletin No. 86, Washington, 1904.

CHAPTER XI.

SYNOPTICAL ACCOUNT OF RECORDED CASES, ARRANGED CHRONOLOGICALLY.

1815. Case I.[1]—M. Gehlen, a professor of chemistry, was working with his colleague Ruhland in the chemical laboratory at Munich at an investigation of the reactions arising from the interaction of arsenic and potassium oxide or potash. The solutions used being somewhat dilute, the odour of the gas was tardy in manifesting itself, and Gehlen, trying to judge the moment when the hydrogen began to combine with the arsenic, sniffed about the apparatus, and thus involuntarily inhaled the gas. Hardly an hour had elapsed, when he was seized with continuous vomiting, shivering, and alarming feebleness, and, later, he passed bloody urine. After considerable suffering, he died on the ninth day.

Ruhland, writing to his friend Guyton de Morveau on 1st April 1815, gives an account of the occurrence as follows:—"My colleague, whom you knew through the Journal which he published for many years, has died in the saddest way. We were preparing together, five days ago, AsH_3 gas. The solution with which we were working being somewhat dilute, the gas was slow to manifest its

[1] *Halle'sche Allgemeine Literaturzeitung*, No. 15, 1815; Buchner's *Toxicologie*, p. 476; *Brit. and For. Med.-Chir. Review*, vol. xx., 1857, p. 521; Geigy, *Beitrag zur Kenntniss der Arsenwasserstoffvergiftung des Menschen*, Basel, 1890.

particular odour. With the intention to fill successively small bottles with the gas, M. Gehlen sought to judge by the odour when the hydrogen gas began to combine with the arsenic, and it was in this way that he was poisoned. Hardly an hour had elapsed when he was attacked with constant vomiting, shivering, and alarming weakness. He died in my arms after nine days of unheard-of suffering, a victim of his zeal for the progress of science."

1836. CASE II.[1]—R. Schindler, a pharmacist, began to evolve AsH_3 gas from a Woulff's bottle at 5.30 P.M. of the 14th April 1836, and thereafter for about two hours respired the gas in the air of his laboratory. Four hours later, he was seized with pains in the loins, shiverings, coldness of the extremities, pain in the epigastrium, vomiting, and bloody urine. These symptoms persisted on following days. In addition, there was dark-brownish discoloration of the skin of his body and a yellow icteric tint of the conjunctivæ. On the sixth day the blood in the urine ceased. On the seventh, there was improvement in his condition generally, which continued. By the end of the seventh week, he was fairly well again. It was reckoned by his brother that he had inhaled gas equal to not more than one-eighth of a grain of metallic arsenic. Curiously enough, Lucas[2] says of this man that "la mort survint le huitième jour et ne fut pas suivie d'autopsie."

1836. CASE III.—In December 1836, a young chemist generated the gas from a mixture of arsenic, zinc, and

[1] *Repertorium für die Pharmacie*, Bd. 69, p. 271; Von Graefe und Walther, *Journal de Chirurgie*, Bd. xxvi. S. 624, 1838; Eulenberg, *Die Lehre von den schädlichen und giftigen Gasen*, 1865; Christison, *On Poisons*, p. 326.

[2] *Op. cit.*

sulphuric acid. He died twenty-four days after. Taylor,[1] who mentions his case, gives no particulars as to the symptoms, although he remarks "but a very small portion of the gas could have entered his lungs."

1841. CASE IV.—Mr. Brittan, aged thirty-one, a chemist and druggist, on 23rd October 1841, while in good health, inhaled on two separate occasions about 150 cubic inches of hydrogen gas for the purpose of producing the shrill voice of Tyndall's experiment. He was at this period engaged in writing a manual of chemistry. Immediately after the second inhalation, he was seized with giddiness and fainting, which were succeeded later by shivering and the passage of two ounces of bloody urine. Shortly afterwards, he was seized with pain in the lower extremities, accompanied by numbness and tingling in these as well as in the upper limbs. These symptoms lasted for about two hours. Then he complained of slight pains in his loins, and was attacked by vomiting which was violent, constant, and continuous for four hours. When he was seen by Dr. O'Reilly,[2] who records the case, his pulse was 90, and feeble, the temperature of the body-surface was lowered, his voice was like a whisper, a condition, however, which came on while inhaling the hydrogen, and he had dull pain in the epigastrium on pressure. The vomited matter was copious in amount and greenish in colour.

Oct. 24.—Vomiting had occurred every hour during the night. The face presented a "copper-colour, or rather a dark reddish-yellow" colour, the rest of the body a greenish-yellow colour, and the conjunctivæ bore a like

[1] *On Poisons*, 3rd edit. 1875, p. 358.
[2] *Dublin Journal of Medical Science*, vol. xx. p. 422; *Brit. and For. Med.-Chir. Review*, vol. xx., 1857, p. 521.

colour to that of the body. There was, however, no xanthopsy. In the evening, he passed about half an ounce of urine, which was still bloody.

Oct. 25.—The pulse was 76, there was occasional hiccough, he had no pain, but he had not passed any more urine.

Oct. 26.—The stomach now retains fluids. Patient had only vomited three times. The jaundice was beginning to disappear. The bowels were freely evacuated, the motions being loaded with bile. No more urine, however, had been passed.

Oct. 27.—The jaundice had nearly disappeared. Patient had only vomited once. No urine had yet been passed. The pulse was 80. The face was somewhat œdematous.

Oct. 28.—Patient had had a restless night. His tongue seemed somewhat large, showing a deep, irregular ulcer on its right side. His breath had an ammoniacal odour. He had not passed any urine, and none was found in bladder on catheterisation. In the evening he appeared to become increasingly drowsy, although there was no loss of memory.

Oct. 29.—Patient had passed seven stools. He had also voided an exceedingly small quantity of urine, which, on standing, deposited a little blood. The pulse numbered 102. By mid-day, there was great weakness, the pulse having fallen to 76. The œdema had increased. He began to sink at 4 P.M., and died at 7 P.M.

Autopsy was held thirty-six hours after death. The following conditions were found:—there was general anasarca of the body; the abdominal integuments were of a slightly greenish colour; and the abdomen itself was greatly distended with gas.

The lungs were completely collapsed, but were natural

in structure. Two pints of a reddish-brown fluid were present in the pleural cavities. The heart was pale and flabby, and its cavities contained no blood. There was a little fluid in the pericardium.

The liver was of a deep-indigo colour, but was normal in size; the gall-bladder was distended with bile. The kidneys were of the same colour as the liver, the left being larger than normal. The stomach was empty, and two inflammatory patches were discovered on the greater curvature. The urinary bladder was empty. The brain and membranes were practically normal.

Dr. O'Reilly found arsenic in the sulphuric acid and zinc used in the experiment, and by further research was able to affirm that the acid was the immediate source of the arsenic. He also found arsenic in the fluid taken from the pleural cavities of deceased. He concluded that the amount of arsenic inhaled as arseniuretted hydrogen was about 12 grains, since he found 6 grains of orpiment (arsenious sulphide) in 200 grains of the acid used, and calculated the equivalents of the sulphide and the arsine as practically the same.

1850. Case V.—Professor Robertson, aged fifty-seven years, professor of chemistry in the Calcutta Medical College, was engaged in demonstrating to his class the method of performing Marsh's test for arsenic. The apparatus, properly charged, was abundantly evolving the arsenical gas, he meanwhile standing between an open door and the apparatus. During the currency of the experiment, a student opened one of the windows of the room, which caused a draught of air to blow the gas about the operator. This he unwittingly inhaled for a short time, but very soon becoming aware of a sense of burning and constriction in his throat, he had abruptly

to leave the class-room. He began to vomit almost immediately thereafter, and continued to do so for some time,—the exact time not being stated,—at the end of which period, the vomited matter consisted of material having the "coffee-grounds" character. He had severe pains in his loins, and passed three or four pints of bloody urine, which he locked up for the purpose of submitting later to chemical examination.

Sixteen hours after the above occurrence he was seen by Dr. Mouat, who noted in him the following symptoms, viz. considerable fever, the skin being hot and dry, the pulse hard; burning pain in the whole course of the alimentary canal; deep-seated pain in the lumbar region; intense restlessness, anxiety, and general uneasiness; pallor of countenance; and general prostration. On the third day, there was tenderness along with a sense of dragging in the left iliac region, and on administration of castor-oil, a copious clay-coloured evacuation, with a tubular, membranous-looking slough, which was ragged in appearance and about four inches in length, was passed. This slough was found on more minute examination to consist of the lining membrane of the rectum with added fibrinous exudation. On the seventh day, he had pain in the right hypochondriac region, and at the end of eighteen hours thereafter, he became jaundiced. By the end of the twenty-second day, all the distressing symptoms had disappeared, although he was left in a weakly condition. The urine, which had been preserved, was examined by Reinsch's process and was found to contain minute traces of arsenic.[1]

1854. Case VI.—A teacher inhaled hydrogen which had been generated from zinc and sulphuric acid for the

[1] Mouat, *Indian Annals of Medical Science*, April 1857, p. 657.

purpose of an experiment, presumably that of Tyndall on the voice. Immediately thereafter, he perceived a sensation of heat in his eyes, weakness of the limbs, with an inclination to faintness and shivering. The symptoms of weakness and faintness, however, passed away later. Next day he voided black urine. When he was examined, his pulse was found to be quiet, his lungs showed no signs of irritation, and his intelligence was quite clear. The urine, which was still black in colour, amounted in quantity to about 200 c.c., and gave on being boiled a plentiful brownish-red coagulum, which was almost identical to that which is formed when blood diluted with water is boiled. No red corpuscles, however, were found in the urine on microscopic examination. At the end of a day and a half, the urine began to get lighter in colour. Examination of the gases evolved from the zinc and sulphuric acid used indicated the presence of arsine gas.

An experiment was made on a dog with the gas produced in the same way as that inhaled by this patient, and the animal exhibited the same general signs of poisoning, and, like the patient, voided bloody urine.[1]

1863. CASE VII.—A young chemist, named C. B., aged twenty-two years, employed in a chemical manufactory, was engaged in researches on the production of colouring matters from anilin, and on the morning of 3rd March 1863, at 7 A.M., he set free a considerable amount of arseniuretted hydrogen gas. An hour later, he was seized with violent pain in the head, but he opened his window only and continued his work for two more hours.

[1] Vogel, *Arch. des Vereins für Arbeiten zur Forderung d. wissenschaftlichen Heilkunde*, 1854, vol. i. Part ii. p. 209; *Brit. and For. Med.-Chir. Review*, Jan. 1854, p. 279; Neubauer und Vogel, *Anleitung zur Analyse des Harns*, 7th edit. 1876, p. 310.

At 10.30 A.M., he took a hearty meal. One hour later, the headache began to become more severe, pain set in in the epigastrium, and he vomited all the food of which he had partaken. He was now taken to La Charité Hospital, and placed under the charge of M. Piorry. During his journey to the hospital he vomited three times. On admission, he was pallid, complained of frontal headache, of pain in the loins, and of a sense of constriction in the lower part of the chest. There were accelerated respiration, little cough, great thirst, and cold extremities, but he was quite intelligent. The pulse was 110, and was full and strong. There was then no abdominal pain, either spontaneous or provoked on pressure. The liver, however, was tender to palpation. Measures were at once adopted to aid the restoration of the body-heat, and these were successful at the end of an hour. About 5 P.M., he passed two foul and copious stools, and about 220 c.c. of red-coloured urine, the latter, however, not showing on microscopic examination any red corpuscles. He vomited much greenish-coloured matter. Acute pain in the head still persisted at night. The conjunctivæ were injected. About 10.30 P.M., his speech became embarrassed, and his replies to questions slow. He was bled to the extent of 500 grammes, which seemed to be followed by almost immediate relief. At 1 A.M., M. Piorry found him in the following state, viz. his face was slightly icteric in colour; the skin hot; the pulse regular and good, numbering 100; his intelligence active, and his responses to answers clear. The vomiting had ceased. The bowel was then washed out, and he was given a bath, after which measures he felt himself better.

March 4.—The face had developed an earthy-yellow colour; the skin was dry; pulse 104; respirations 40;

he had great thirst; he had now a listless air; there was some congestion of the lungs posteriorly; and he had passed no urine.

March 5.—There was complete anuria. The tongue and lips were covered with a smoky-looking fur. The skin of body was now of a bronze colour. The pulse during the day became weaker, and latterly almost imperceptible. The breathing became quickened and embarrassed. He gradually became unconscious, and died in the evening.

Autopsy.—This was performed twenty-four hours after death. There was no congestion of any organ except of the liver, in which, however, there was no alteration of the hepatic cells. The spleen was softened. The kidneys were augmented in volume, the organs being injected throughout, but especially in the tubular substance. They were of a violet colour. Both ventricles of the heart contained voluminous clot, partly fibrinous and partly of black clotted blood. On microscopic examination, the red corpuscles showed no change.[1]

1863. Case VIII.—On the 2nd December 1863, the apothecary Mettrier was making, with two of his colleagues, an examination chemically of the intestines of a girl who had been poisoned. On testing with Marsh's apparatus, he found abundant traces of arsenic, so much so, indeed, that the twelfth porcelain cup-head and cup used to receive the arsenical deposit were quite covered with the deposit. During the experiment, he perceived a marked odour of garlic. By the early evening the work was finished. Mettrier took his food that night as usual, and,

[1] Ollivier, *Gaz. des Hôpitaux*, 1863, p. 128; *Comptes Rendus des Mémoires de la Société de Biologie*, iii. series, vol. v., 1863; *Chemical News*, vol. viii., 1863, p. 307.

except that he felt a little out of sorts, went to bed at 10 P.M. Early in the morning he awoke with a violent headache and symptoms of disordered digestion, coldness in his extremities, shiverings, and a general feeling of dejection. Inability to sleep prevailed for a few nights after. After some days he recovered.[1]

1870. CASE IX.—On 12th January 1870, a working mechanic named C., and aged thirty years, was called to do some repairs of apparatus in a chemical work in Lyons. The repair consisted in welding a piece of metal apparatus, and he undertook the work under the supervision and with the assistance of a chemist of the chemical work named L., aged twenty-nine years. Both were at the time in robust health. To accomplish the repair the metal was heated by a flame composed of a mixture of hydrogen and air, the former gas being generated in a suitable apparatus in the form of a brazing-lamp. The machine, of which the part in question was under repair, stood in a large workshop open to the air on all sides. During the operations, the flame in the brazing-lamp became unsatisfactory, and L., believing it due to a want of hydrogen, added more zinc and, what at the time he believed to be, more sulphuric acid. Still the flame was not satisfactory. He thereupon opened up the apparatus to ascertain the cause. Both of them then noticed that the gas which was coming off was nauseating and possessed a garlic odour, but neither of them realised its import. A few minutes afterwards L. was called away to speak with the manager, leaving the other to continue the work as best he could. The manager during his conversation with L., observed that L. was changed in appearance, and asked him if he felt well enough. To

[1] Chevallier, *Journ. de Chimie médicale*, iv. series, 1864.

this L. replied that he was sick, that he thought his breakfast had disagreed with him. Soon after, L. began to vomit freely. Meanwhile C., the mechanic, continuing the work which was proceeding poorly, tried by himself to discover the cause of the failure of the hydrogen brazing-lamp. But soon after, he also began to feel ill, had to leave the workshop to vomit, and, having at the same time a strong desire to micturate, he discovered, to his surprise, that he was passing bloody urine. He returned to the workshop and spoke to some of the workmen of what had occurred, and these, having in the interval heard of the illness of L., at once declared that he had been poisoned. They then rolled him in blankets and hurriedly took him to a pharmacy in the town, where 25 grammes of magnesia hydrate were given him. He was thereafter taken home. When seen by Dr. Valette an hour after, his condition was as follows:—his face was choleraic in aspect, the conjunctivæ were jaundiced, his body was cold, and his pulse numbered 90. He had very painful and constant vomiting, had passed two stools, complained of pains in his lower limbs, but withal was quite clear in mind. He was given a vapour bath.

Jan. 13.—His condition was about the same as before. His feebleness was very marked; the acts of vomiting were as frequent and as painful; and he had only passed about an ounce of blackish bloody urine. His eyes were now distinctly icteric in hue. He was prescribed hydrated peroxide of iron, of which in all he got that day about 15 grammes. The urine was tested by a chemist, who obtained indications of arsenic by Marsh's process.

Jan. 14.—The vomiting still continued, but was not so frequent. He had perspired much because of the vapour baths which had been prescribed.

Jan. 15. — Improvement was observable. He had vomited only once since yesterday. The jaundice of conjunctivæ had disappeared. He had passed urine to the amount of 250 c.c., which, however, was still strongly blood-coloured. His pulse numbered 96, and his temperature was 37·25° C.

Jan. 16.—Vomiting had ceased. Urine had been passed of similar amount to last, and was now of a saffron colour.

Jan. 17.—Vomiting had returned, as also had pain in the head and epigastrium. He had great thirst. Conjunctival jaundice likewise had returned. The pulse was 76, and the temperature 37° C. One and a half litres of urine had been passed, which was of less high colour than formerly, and contained less sediment on standing. By the 25th January he seemed to be quite recovered, except for weakness in the limbs.

L. was also seen on 12th January, and was found to have like symptoms to those of the previous patient, although, perhaps, less severe. The sclerotics were injected with blood, and were jaundiced. The pulse was small and frequent, the skin cold, vomiting was almost constant, and there was great feebleness, but no pain.

Jan. 13.—He had vomited but once. No urine had been passed during the previous twenty-four hours.

Jan. 14-15.—His condition generally was as the day before, but on the 15th he had passed about half an ounce of urine, dark-red, indeed almost black in colour. The pulse was 84, and the temperature 37·35° C.

Jan. 16.—Vomiting was at longer intervals. Drinks were swallowed, but with pain. He was thirsty. Otherwise, he was as before.

Jan. 17.—He had vomited once only since the day

before, and had passed about one ounce of dark-coloured urine.

Jan. 18.—Condition much the same. Urine in amount and colour had been passed as on day previous. This was his condition generally until 21st January, when he passed a bloody stool. Besides, an eruption of blood-tinged papules appeared on this date on the abdomen, thighs, and loins, not unlike purpuric measles. There was no fever, but there was almost complete suppression of urine, half an ounce only having been voided. This state of the urinary organs continued up till the 24-25th January, when he passed about 100 c.c. of urine per twenty-four hours. This quantity was voided daily during the next three succeeding days. During these three days also he had three bloody stools. During this period, moreover, he seemed entirely indifferent to all that passed around him, although he answered all questions put to him.

Feb. 1.—Restlessness became more marked, and acts of vomiting more frequent. He had great thirst and much difficulty in swallowing. He suffered from epistaxis, which was oozing in character. His gums, up till now anæmic, became bloody and began to ooze of blood, as did also the mucous membrane of the mouth. There was a disagreeable odour from the mouth. The skin eruption now assumed a violet tint.

Feb. 2.—The bleeding from gums continued, and oozing of blood from the prepuce and glans penis had also set in. The urine, however, had now become abundant and clear. It was estimated that from the time the bleeding had commenced he had lost in all about 300 to 400 grammes of blood.

Inhalations of oxygen were tried during the two

following days, the only apparent effect, however, being a reduction in the loss of blood. The temperature had now fallen to 36·35° C. This was his condition till the 8th of February, when he began to exhibit a somnolent tendency, although he could be awakened easily, and was then quite clear in intellect. The skin of his face had now a brownish tint.

Feb. 9.—On this date he vomited blood, and fainted twice in the early part of the day. He died in the course of the day while in the act of conveying some fluid to his mouth.

The cause of the accident consisted in the fact that when L. replenished the hydrogen lamp, he added by mistake, the label of the bottle having become partly torn and therefore illegible, a solution of arsenic acid instead of sulphuric acid.[1]

1872. Case X.—On 22nd May 1872, a professor of physics was making an experiment on himself by inhaling hydrogen gas, which he generated from zinc and sulphuric acid. The object of the experiment was to demonstrate the shrill voice of Tyndall's experiment. He inhaled the gas for the first time at 11 A.M., and again a second time the same day at 4 P.M. He estimated the amount of gas evolved to be between 14 and 15 litres. He felt, however, no active discomfort thereafter, but he perceived that the urine passed by him afterwards was bloody. For days after, the urine was of a high-yellow or saffron colour. His skin became jaundiced of a highly-yellow colour. By the 25th, however, the jaundice began to lighten in colour, and by the 10th of June, it had entirely disappeared. The reddish-yellow urine vanished with the

[1] Valette, *Lyon Médicale*, March 27, 1870, p. 440; Woodman and Tidy, *Handy-Book of Forensic Medicine*, p. 166.

icterus. On one day only did he have a bloody stool, and on one occasion only, epistaxis.

His assistant, a much younger man, had inhaled from 16 to 18 litres of the gas, and twenty-four hours later he was jaundiced, and passed bloody urine like his chief. Both recovered.[1]

1873. Case XI.—Nine men were engaged in a lead work in the process of extracting silver from lead and zinc ores by using hydrochloric acid which was heated. All the materials, including the acid, were afterwards found to be arsenical, indeed, to contain 0·027 per cent of arsenic. The men worked the process by what was essentially a large Marsh apparatus. Symptoms of illness began to show themselves in the workmen on the day of operation, the 1st of September, and on the 2nd all of them were ill.

1. H. K., aged twenty-two years, felt ill at mid-day, his symptoms being want of appetite, sickness, giddiness, eructations, depression, and oppression of breathing. That night he slept only for one and a half hours. Next day, however, he went back to work, but he felt unable for it. He passed some bloody urine, the act being accompanied by pain. The following day he was jaundiced. He had difficulty in breathing, headache, dryness of mouth, thirst, pains in his joints, had again passed bloody urine, and had had one blood-coloured stool. His pulse numbered 100. There was no arsenic, however, found in the urine on chemical examination.

2. J. Z., aged nineteen years, had observed while engaged in the above process that the fumes given off had a garlicky odour. Five hours later, he was seized with headache, giddiness, vomiting, and at night, he passed

[1] Ollivier, *Comptes Rendus de Biologie*, 1873.

some bloody urine. Next day, he had marked jaundice of the conjunctivæ, his pulse was frequent, and he had voided a little bloody urine, but had passed no further stools. By 5th September, his urine was normal. He recovered.

3. C. B., director, was ill one day only. He was, however, only a short time near the apparatus.

4. L. M., aged thirty-seven years, was found on the evening of 2nd September to be suffering from depression, headache, dragging sensation in abdomen, and from vomiting. He had passed a liquid stool and some bloody urine. Later in the evening, he became delirious and somnolent. Next day the conjunctivæ were jaundiced, his extremities were cold, he had hiccough, and, later, sweating supervened. His pulse was small, numbering between 150 and 160. For a number of days afterwards, the urine continued to be bloody, and his general condition serious. He died.

5. T. S. supervised the work for two days. On the evening of the second day he had abdominal pain, vomiting, headache, and depression. On the following day he grew worse. He had pain in the loins, thirst, and his conjunctivæ had become yellow in colour. The urine was scanty and bloody. He had had a dark-brown stool. Anuria then developed. His morning pulse was 110, and that of the evening 130. Next day the anuria continued, his pulse being 130, and his temperature 38·5° C. Next day, he became delirious, and by the day following, comatose, the pulse being 160. He died on the succeeding day.

6. M. R., aged thirty-six years, took ill on 1st September with symptoms exactly like those of the previous patient. He died on 3rd September.

7. J. J., aged fifty-two years; (8) M. S., aged nineteen years; and (9) C. S., aged forty-three years, sickened on 2nd September and exhibited similar symptoms, but they all recovered, although they were only able to return to work after some months.

Another workman, who worked in the vicinity of the apparatus, complained for some hours of headache and nausea, which, however, quickly passed away.

Post-mortem examinations were made of the bodies of the men who died. In the case of L. M., it was performed thirty-six hours after death. The following were the main features of the examination:—The skin was of a dirty-yellow colour. *Brain.*—The dura mater was anæmic, and the pia mater congested. *Chest.*—The mucous membrane of trachea, larynx, and mouth was of a greenish-yellow colour, and that of the gullet of a dirty-yellow tint. *Heart.*—The left ventricle was empty, but the right auricle contained a little blood. *Abdomen.*—The liver was moderately enlarged but not congested, its colour being greenish-yellow; the gall-bladder was half-full of bile. The small intestine was empty; the spleen was normal in size, firm, and not congested; the kidneys were much congested, but firm, their colour being dark-red.

The body of T. S. was examined twenty-eight hours after death. The skin was yellowish in colour. *Brain.*—Dura mater was anæmic, the pia mater hyperæmic. The brain substance was neither hyperæmic nor yellow in colour. *Chest.*—The heart conditions were the same as in previous case. *Abdomen.*—The liver was normal in size, its tissue compact, not congested, its colour being yellowish-brown. The small intestine was brownish-red in colour. The spleen was normal in size, firm in texture, and brownish-black in colour. The kidneys were normal

in size, very hyperæmic, and dark-red in colour; on section, they were brownish-black in colour.

The body of M. R. was examined sixty hours after death. The skin was bluish-green in colour. The brain and meninges were similar to the previous cases, as were also the conditions of the heart. The liver was enlarged, anæmic, softer in texture than normal, and slaty-blue in colour. The gall-bladder was very full of bile. The spleen was much enlarged, hyperæmic, soft in consistence, and dark-red in colour. The kidneys were normal in size, very hyperæmic, and also dark-red in colour.[1] Arsenic was found by analysis in the organs of the deceased.

1878. CASE XII.—On 16th July 1878, four Italian pedlars were employed for about five hours in filling toy rubber-balloons with hydrogen gas which they generated from zinc and sulphuric acid. The room in which the operation was being conducted contained about 700 cubic feet of space only, and was ventilated solely by a broken window-frame. During the filling process they perceived no garlicky odour from the gas. About an hour later, they showed the following signs of illness, viz. tiredness, trembling of limbs, giddiness, headache, nausea, and, still later, vomiting and sleeplessness. In the morning, there was jaundice of the skin, with bloody urine and painful micturition. They were taken to hospital, when their condition was found to be, generally, as follows:—

1. A. B., aged twenty-five years, who had inhaled the gas for half an hour, had jaundice, a pulse strong and full, numbering 100, temperature 38·6° C., respirations 30, and his urine, though free as to amount, was dark-yellow in

[1] Trost, *Vierteljahrsschrift für gerichtliche und öffentliche Medicin*, vol. xviii., 1873, p. 369; Layet, *L'Hygiène industrielle*, Paris, 1897, pp. 493-497; Sonnenschein, *Handbuch der gerichtliche Medicin*.

colour, but contained no blood. The internal organs were found to be normal.

On 20th July the jaundice was disappearing, and although the urine still appeared slightly bilious-looking, it contained no blood. Some of the red blood-corpuscles taken from the blood-stream were found on microscopic examination to be shrivelled.

July 21.—The spleen was now felt to be enlarged. By the end of July he was convalescent.

2. C. A. had inhaled the gas for two hours. On 18th July, his skin was of a citron-yellow colour. The liver area seemed rather smaller than normal. Spleen was normal. He was passing painlessly very bloody urine. His pulse was 108, temperature 38° C., and respirations 36. Next day, the liver area still appeared diminished. He had voided 2200 c.c. of urine during the past twenty-four hours, of a sp. gr. of 1,016, which, however, was less bloody than before, but which now showed much sediment, which microscopically was found to consist mainly of epithelial cells and isolated red and white blood-corpuscles. This state of urine steadily improved, and by 2nd August, he was convalescent.

3. B. St., aged thirty years, had worked for three hours at the process. On 18th July, he was found to have very dark jaundice of skin. His pulse numbered 120, his heart was feeble in action, respirations were 36, and his temperature 38·2° C. He complained of pain in the stomach and chest, and of a feeling of oppression over the regions of liver and kidneys. He was passing bloody urine, accompanied by strangury. Next day his skin had assumed a dirty greyish-yellow colour. The liver area was diminished. There was no vomiting, but he had a burning sensation in the mouth. He had voided a stool which

contained both blood and bile. He was still passing bloody urine, its total amount during previous twenty-four hours being 1800 c.c., of a sp. gr. of 1,015, and of weakly acid reaction. It deposited a sediment consisting of epithelium and red corpuscles.

July 20.—Urine was now of a dirty brownish-red colour. The spleen had become enlarged.

July 25.—The urine still contained a little blood and albumin. The spleen was still enlarged. He was convalescent by 4th August.

4. C. G., aged thirty-three years, had worked with the gas for three hours. His first symptoms showed bilious vomiting, and a sense of oppression over liver and kidneys. He was voiding bloody urine in drops, the act being accompanied by tenesmus and strangury. He had, however, no headache.

July 19.—The bilious vomiting continued. The liver area was less than normal. He had had no motion of the bowels, but had much desire for micturition. He had only passed during the previous twenty-four hours 150 c.c. of urine, which showed much bloody sediment, in which were found red corpuscles. The urine had a sp. gr. of 1,007, and it contained hæmoglobin.

July 20.—He complained now of dragging pain in liver and kidneys. The jaundice was beginning to disappear. There was complete anuria, the bladder being found to be empty.

July 23.—He passed to-day for the first time since the 20th urine amounting in quantity to 40 c.c., which was of a brownish-red colour. Next day, he complained of pain in the head. Amount of urine voided, 50 c.c., dirty-red in colour.

July 25.—He had much pain over liver, and on

examination that organ was found to be enlarged. No further urine had been voided.

July 26.—Urine was passed to amount of 50 c.c. He died at 5 P.M.[1] Arsenic was found in the blood, bile, brain, and urine of deceased.

1879. CASE XIII.—Dr. X. turned ill unexpectedly at 5 P.M. of the 1st November 1879, with severe shivering and general feeling of illness. He became feverish as night advanced, with troubled sleep. He began to perspire toward morning. His urine at bedtime was copious in quantity, but was blood-red in colour and without sediment. It contained hæmatin. There were great weakness and loss of appetite. Next day, the fever had gone. There was a distinctly jaundiced condition of the sclerotics, of the forehead, and of the skin of the body generally. His tongue was furred. The urine was still red in colour, but acid in reaction.

Nov. 3.—He had had a better night, and himself felt better. The urine was now clear, and non-albuminous. He had a slight shivering in the evening. Next day, the urine had become reddish-brown in colour, was acid in reaction, contained much albumin, and microscopically showed red corpuscles. The diagnosis up till this time was periodic hæmoglobinuria.

Nov. 5.—Urine had now become clear and straw-coloured, and did not now contain albumin. He felt well enough to resume his duties.

On 6th November he discovered for the first time that another lecturer and two pupils had been attacked as well as himself with like symptoms on the same day and under precisely similar conditions. It appeared that all of them

[1] Wachter, *Vierteljahrsschrift für gerichtliche Medicin*, vol. xxviii. Part ii. 1878; Layet, *op. cit.*

were engaged on that day in experimenting on their voices with hydrogen gas, which was generated from zinc and sulphuric acid.

The three others were more or less affected like himself with bloody urine and other symptoms, and one of the pupils had jaundice. By the 7th November, however, their symptoms having mostly vanished, and a likely common source of the trouble having been discovered, the acid used in generating the gas was analysed, and was found, relatively speaking, to contain much arsenic.[1]

1884. CASE XIV.—A workman in an anilin manufactory, aged forty-three years, took ill on the evening of the 15th November 1883. During the day he had been working in the vicinity of an apparatus from which gases were being evolved freely, and some of which he respired. Soon after going home from work, he began to take rigors, which were followed by pain in the head and loins, and by much vomiting. He passed a fair night, but voided only about 150 c.c. of black urine. Dr. Coester, who was called to see him, was inclined at first to look upon his illness as a case of anilin poisoning, but after inquiry at the work, was compelled to conclude that it was one of poisoning by AsH_3 gas, possibly by reason of impurities in the hydrochloric acid and zinc which were being employed in the process. This diagnosis was confirmed during the course of the illness.

The condition of the patient, as noted by Dr. Coester on the morning of the 16th, when he first saw him, was briefly as follows:—He complained of pain in the head and of lumbar pains, and he was and had been vomiting. He passed in presence of the doctor about 50 c.c. of blackish urine. His temperature was 38·5° C., and the pulse 88 and

[1] Eitner, *Berliner klinische Wochenschrift*, vol. xiii., 1880, p. 256.

regular. On examination of the internal organs nothing was found amiss. Analysis of the urine showed that it contained hæmoglobin but no blood corpuscles. Next day the patient felt a little better, but a very marked jaundice had now developed. He had no pain, and he had vomited once only. He had voided a very small quantity of urine. He had still a dragging feeling at the loins. The liver was found to be distinctly enlarged, as was also the spleen. He had occasional stupor accompanied by slight delirium. During the following days there was almost complete anuria; indeed, it was estimated that he had only passed on the average about 5 c.c. of urine per hour during the twenty-four hours.

Nov. 21.—Convulsive contractions of the muscles of the forearm had now appeared, and by the following day these had extended to the eye muscles. Although he was perspiring freely from the warm baths which had been given him since the 21st, anuria was still practically present.

Nov. 25.—He died suddenly in the morning while in the act of trying to raise himself in bed.

Post-mortem examination was made of his body sixty hours after his death by Dr. Pfeiffer, in the interests of justice. It gave, however, almost negative results owing to the advanced state of decomposition of the body. The liver was found to be firm in consistence, and not to be enlarged. The kidneys and spleen were both enlarged, but were black and decomposed. Analysis of the liver proved that it contained arsenic.[1]

1886. Case XV.—In a chemical work at Basle, five workmen took ill on 2nd February 1886, while engaged in the manufacture of zinc chloride from zinc and hydro-

[1] Coester, *Berliner klinische Wochenschrift*, vol. xxi., 1884, p. 209.

chloric acid. They had the same symptoms in common, which were evidently those of poisoning.

1. J. P., aged forty-eight years, gave the following information on 10th February concerning the circumstances of the 2nd. On the afternoon of that day, he was seized with marked indisposition, vomiting, headache, smarting in the eyes, and dryness in the throat. In spite of these feelings, however, and although he did not feel much better, he went out next morning to resume his work, but feeling quite unfit and gradually becoming worse, he was compelled to return home after mid-day. To the foregoing symptoms were added bloody urine, jaundice, and particularly, great weakness and shaking of the limbs. After treatment, these began to improve: the urine to become clearer; the appetite to return; and the jaundice and weakness to disappear.

Feb. 10.—The eyes were still discoloured, of a light-yellow colour. The blood-colouring matter had now disappeared entirely from the urine, but the patient was still anæmic.

2. J. R., aged fifty-eight, was seized with the first symptoms of poisoning on the early morning of 2nd February, in the form of bloody urine. The urine remained quite black until the evening, and his general state of health was bad. From the 3rd February he was confined to bed by reason of the jaundice. The other symptoms, as well as their course, were like to those of the preceding patient. He eventually recovered.

3. F. K., aged forty-five years, was engaged for two days at the same employment as the others. On 2nd February at 8.30 A.M., he was suddenly seized with much giddiness, violent pain in the stomach, and an inclination to vomit. At 2.30 P.M., blood appeared in the urine. At

5 P.M., there was a little improvement in his condition after a bath. On his way home, however, he experienced great weakness. The next day there was jaundice. After that, his case was like the former cases.

Cases 4 and 5 of this series were identical generally to the rest, both as to symptoms and progress. Analysis of the hydrochloric acid used proved it to be contaminated with arsenic.[1]

1887. CASE XVI.—This case was treated in the Basle Town Hospital by Dr. Geigy, who records the particulars of the symptoms.[2] In the *Correspondenzblatt für Schweizer Aertze*, 1887, p. 727, Professor Immermann had already given an account of the case under the title of "A Case of Acute Blood-Solution."

The facts are these: C. C. S., aged forty-eight years, worker in a chemical work, who was mostly employed in the manufacture of antipyrin, was set to work to make zinc chloride from zinc scraps and crude hydrochloric acid. He took suddenly ill in the afternoon with violent pains in the loins, giddiness, headache, and shaking of the whole body and limbs. Soon afterwards, he had the desire to micturate, and he passed a small amount of urine, which was quite black in colour. Then there followed immediately vomiting and diarrhœa. He had to be assisted home. This happened on 3rd May. After treatment at home by the works doctor, he was sent into hospital on 5th May. His condition on the 4th was as follows:—his skin had become bronze-coloured; vomiting persisted throughout the whole day; he had passed a thin brownish-red stool; and there were great debility and depression.

[1] Von Sury-Bienz, *Vierteljahrsschrift für gerichtliche Medicin*, 1888, p. 353.

[2] Geigy, *op. cit.* p. 31.

In addition, he had much pain in the region of the liver and stomach. His urine was scanty in quantity, and micturition was accompanied by a burning sensation. He experienced much thirst and dryness of the throat.

On his admission to hospital on the 5th, his temperature was 37·2° C., respirations 24, and pulse 80. His skin was bronze-coloured, the conjunctivæ being between a yellowish-red and a reddish-brown colour. The tongue was much furred, and the mucous membrane of the mouth and pharynx was dark-red in appearance.

May 6.—Up till now since admission into hospital, he had passed only 15 c.c. of urine, which was dark-reddish in colour, but showed no red corpuscles on microscopic examination. Spectroscopic examination, made by Professor Bunge, indicated the presence of oxy-hæmoglobin and met-hæmoglobin. It also contained traces of biliary colouring matter. Microscopic examination of the blood revealed considerable diminution in number of the red corpuscles and remnants of broken-down corpuscles. Computation of the red corpuscles by the Thoma-Zeiss process gave from 885,000 to 920,000 per cubic millimetre. The hæmoglobin-value indicated 57 per cent by Gower's hæmoglobinimeter. The spleen and liver were both swollen and sensitive to pressure. The skin colour and the tint of the conjunctivæ had changed to a darkish-yellow. Anuria was complete. Otherwise, his condition had undergone no change.

May 7.—There was no fever; pulse was normal, numbering 86; he had the feeling of heavy oppression; headache and pain of liver were passing away. There was no vomiting. Stools passed were thin, dark-brown, and stained with bile. The liver was not much enlarged. On the whole, patient felt somewhat better.

May 8.—Patient had been very restless during the night. He was apathetic and had become less sensible. Anuria was substantially complete. He felt very feeble.

May 9.—The jaundice of skin was now a little more yellow in colour, the conjunctivæ being ochre-coloured. The tongue was furred and dry. There was no fever, the pulse being 84, full and hard. He became comatose, and died in the early evening.

A post-mortem was made on 10th May by Professor Roth, and the following facts were found:—The skin was pale-yellow in colour, as were also the conjunctivæ.

Brain.—The membranes were anæmic and œdematous, especially on the left side, but they were transparent. The right ventricle contained clear fluid. The substance of the organ itself was anæmic.

Chest.—The lungs were somewhat collapsed and œdematous. The pericardium contained about 25 c.c. of coffee-coloured fluid. The right cavities of the heart were collapsed, the right auricle containing a little dark blood, and the right ventricle, some dirty brownish-red fluid. In the front wall of the right ventricle, millet-seed-like bodies of a yellowish colour were found, which on microscopic examination showed fatty degeneration. The valves of right side were normal. The left ventricle walls were hypertrophied, showed a single fatty area. Its cavity was empty. The mitral valve was roughened. The heart-muscle generally exhibited fatty degeneration.

Abdomen.—The spleen was somewhat enlarged, and its capsule rugose. On section it was brownish-red in colour, the Malpighian corpuscles were distinct, and its substance was moderately tough in consistence. The supra-renal capsules were, on section, greyish-red in colour, and their cellular tissues were œdematous and were surrounded by

a fatty capsule. The left kidney was chocolate coloured, with numerous punctiform extravasations, was somewhat enlarged, its surface smooth, the capsule being easily stripped. On section, there was an almost black colour of the medullary substance, the pelvis being pale. At the mouth of the ureter was a brownish-red deposit, but the entire mucous membrane was pale. The right kidney was also enlarged, was brown in colour, with some patches of a slaty colour, and was smooth on the surface. On section, it was like the other. On microscopic examination, the parenchymatous tissue was cloudy and tumefied, and showed droplets of fat. The tubules were full of isolated cylinders or casts, brownish, yellow, or white in colour, and occasionally, there were besides some isolated brown homogeneous cylinders. In the lumen, here and there, were some large cells, and in the medulla, red corpuscles and numerous glistening crystals, the latter being insoluble in hydrochloric acid, probably oxalate of lime. The liver was somewhat enlarged, and was greyish-brown in colour. On section, it was uniformly bright-grey in colour, with some whitish spots here and there. On microscopic examination the cells were seen to be large, finely granular, but with no fatty droplets. In many of the cells of the middle and inner zones of the acini was a brownish pigment. The gall-bladder was full of a greenish fluid, and its inner lining was tinged of the same colour.

1888. CASE XVII.—V. B., aged twenty-eight years, had worked for two years in a Basle anilin-colour factory, and at the time when he took ill was engaged in the process of making Congo-red, which is produced by adding tin-dust and hydrochloric acid to toluidin. He began to make this colour-stuff on the 19th January 1888. In the evening of that day he felt coldness in the hands and feet, with pain

in the stomach, succeeded by vomiting. The urine which he voided that evening exhibited nothing unusual.

Next day he was somewhat better, the stomach-ache and vomiting had ceased, but now his urine was of a dark-brown colour, and he had dysuria. Next morning, 21st January, his skin had developed a conspicuous brownish colour, and there was redness of the conjunctivæ. He had had a normal stool. His appetite had disappeared, but he had no headache. In the evening, his urine remained of a black colour. He was sent into hospital on the 23rd.

His condition when admitted into hospital was as follows:—Temperature was 37·9° C.; pulse 100, and of low tension; respirations 20 per minute. His face was of a dirty-yellow colour, almost ranging to reddish, as was also the skin of the body. The conjunctivæ were rusty-coloured. The tongue was coated, and he had dryness of the mouth. On examination, his internal organs were found to be normal. His urine was dark brownish-yellow in colour, contained albumin and hæmoglobin, but was free from biliary colouring matters. It measured in amount 810 c.c. Microscopically, it showed isolated yellowish-brown casts, but no red or white blood-corpuscles. The blood was found to contain 2,920,000 red corpuscles per cubic millimetre, and a hæmoglobin value of 62 per cent. The corpuscles showed little tendency to form rouleaux, and there were only a few broken-down cells or shadows. The plasma contained free oxy-hæmoglobin. From this date until his discharge from the hospital on 4th February he gradually improved without any untoward symptom.[1] Arsenic found in the tin and acid.

1871. Case XVIII.—Dr. Martineau reported this case. It was of a druggist's assistant, aged twenty-four years,

[1] Geigy, *op. cit.* p. 36.

who was treated in the Hôtel Dieu, Paris. For two days he had had constant vomiting of green matter, accompanied by constipation. Though originally a strong man, he was found to be very ill on admission. His face was of a livid tint, the lips were cyanotic, the point of the nose cold, and his tongue coated with a blackish fur. His lower limbs were also cold and cyanosed in appearance, the toe-nails being bluish. His temperature was subnormal, being 35·2° C. His pulse was small and scarcely perceptible to the finger. His voice was feeble, and he had great thirst. There was absolute anuria. In the evening, pains and cramps of the muscles of the arms supervened, with great irritation and jactitation. Sixty-six hours after the commencement of the vomiting he died.

On post-mortem examination of the body, hyperæmia of the entire intestinal tract, with petechiæ, was found. The appearance of the liver indicated the results of phosphorus poisoning or of some acute infectious disease, because of its fatty appearance. There were hyperæmia and cloudy swelling of the kidneys, and hæmorrhages in pericardium and endocardium. The membranes of the brain were in the condition of recent inflammation, and the brain substance was hyperæmic. Analysis of the contents of the stomach and liver showed the presence of arsenic.[1]

1885. Case XIX.—The cases under this heading are recorded by Mr. Freer of Stourbridge.[2] They open up the very vexed question whether from arsenical poisoning by wall-paper the cause is minute floating particles of arsenic, or arseniuretted hydrogen, or some other gaseous arsenical

[1] The only reference to this case is given in Schickhardt's paper in *Münchener med. Wochenschrift*, xxxviii. 26, 1891, and is there given as *L'Union*, No. 45, 1871. We have consulted *L'Union Médicale*, 1871, but cannot find any note of the case therein. The reference may be *L'Union Thérapeutique*, but we have not been able to obtain this journal.

[2] *Brit. Med. Journ.* vol. i., 1885, p. 1246.

compound which has been disengaged from an admittedly arsenical wall-paper by the action of moulds which have grown in the decomposing paste with which the wall-paper has been hung, or partly from both causes. We do not stop here to discuss this point. The cases have been included merely because Schickhardt [1] has deemed them to be due to poisoning by arseniuretted hydrogen. But we have dealt with this question in another chapter (*vide* Chap. X.).

In the six cases which compose this series, jaundice was a symptom common to them all. Mr. Freer, who narrates the facts, does not himself attribute them to poisoning by arseniuretted hydrogen poisoning, but records them as being illustrative of the singular uniformity of effect produced by arsenic upon the biliary apparatus.

On 20th September he was called to see a boy and a girl, aged nine and ten respectively, children of a gentleman who had lately gone into a renovated and enlarged house. They were suffering from vomiting, well-marked jaundice, tenderness of epigastrium, and furred tongue. On 30th October, he was again summoned to see another boy and girl of the same family, but a little older in years. Their symptoms were precisely alike, and they recovered like the others after treatment. He suspected the drains, but could get no evidence of causal relationship. Once more, on 12th November, he was called to see two older sisters, aged eighteen and sixteen respectively, who also were jaundiced and had the same symptoms as the others. Nothing was seen on examination of the dining-room except a little damp on the wall-paper, which he examined more closely. The wall-paper was a temporary paper of blue tint, relieved by white figuring. He scraped off some of the white dust and, submitting it and a piece of the paper itself to

[1] *Op. cit.*

chemical tests, he found arsenic present in large amount. On visiting the play-room, where the children had lately passed more time than usual, he found the walls covered with a pale paper with a relief pattern, which was different from that of the dining-room. Examination chemically of this paper also revealed the presence of arsenic in its pigments. He was of opinion that the jaundice was the result of tumefaction of the mouth of the common gall-duct, caused by the inhaled arsenic.

CHAPTER XII.

SYNOPTICAL ACCOUNT OF RECORDED CASES (*Continued*).

1888. CASE XX.—Dütting in his inaugural thesis[1] gives the following account of a series of six cases of Italian pedlars which arose from filling toy-balloons with hydrogen gas, and which were treated in the municipal hospital of Altona by Dr. Käster.

1. P. B., aged thirty-nine years, was one of these six persons. This man was more or less intimately engaged on 22nd May 1887, in the above occupation. He had from early morning till 3 P.M. worked at the operation in a small unventilated apartment. At no time during the process did he perceive anything unusual. When he finished, however, he felt a dull constriction and slight discomfort in his head, which latter passed away later. While working with the gas, he did perceive an odour of garlic, but this he attributed to the hydrogen, and he was not aware that it indicated anything harmful. The feeling of constriction in the head began to increase in severity, and, shortly after, he experienced marked depression and a dull pain in the head, which became more and more violent, and which was accompanied by great general feeling of weakness, and, by and bye, by intense

[1] *Ueber einige Fälle von Vergiftung durch Inhalation von Arsenicasserstoff.* Freiburg, 1888.

faintness and weakness of the limbs. After this, nausea accompanied by vomiting ensued, which continued the whole night and the following morning. The vomited matter consisted of a greenish fluid with a bitter taste. He had violent cutting and stinging pains in the gastric region. He was unable to sleep that night and the following night. He had a strong desire for micturition, which when successful was painful, the urine passed being of a dark-red colour. The next morning he was no better, and in the afternoon was sent into hospital.

The report of 23rd May was as follows:—He was a strong, robust, well-made man, and was well nourished. He seemed to be suffering much, was restless, and complained a great deal of severe depression, of much pain in the head and giddiness, of a doughy taste in the mouth, intense stinging and cutting pains in the epigastrium, dull pains in the loins, and of almost insufferable itchiness and pruritus of the skin of the extremities. His hands and feet felt very cold, his forehead was covered with perspiration, his skin jaundiced, and his tongue was much coated. The respirations numbered 30 per minute, the act of respiration being painful and causing him to groan, yet there was no contraction of the lower part of the thorax. The pulse was feeble, small, and frequent, numbering 120 per minute. Physical examination of lungs and heart revealed nothing abnormal, the abdomen was not swollen, the areas of splenic and hepatic dulness being normal. He was vomiting much tenacious fluid material containing bile and mucus, and was not able to retain medicaments or food. The small quantity of urine, which was passed in drops and with pain, was highly coloured with blood, had a weakly acid reaction, and its microscopic examination showed white and numerous red

shrunken corpuscles, in addition to fatty and blood casts. He had copious thin and greenish-coloured stools. His evening temperature was 38·6° C.

May 24.—Patient was so uneasy that he could not sleep. He complained of great thirst. He thought that he was going to be paralysed in the legs. He had only passed a few drops of blood *per urethram*. The vomiting continued violently. Diarrhœa continued. Microscopic examination of the blood drawn from the finger showed a marked variety of forms of red corpuscles; some were mulberry-shaped, others were crenated, others again were smaller and paler than usual, while others were quite normal, forming themselves into rouleaux. Some, moreover, were shadow-corpuscles, and others were decayed in small granules. Temperature was 37·6° C. The pulse was small and thin.

May 25.—He had passed a very restless night, and felt uncommonly weak and miserable, which gave him the impression of sinking. The pains in the head and hepatic region were not so severe; there was a feeling of heaviness in the legs; and there was great itch in the skin of the extremities. The skin was coloured deep yellowish-grey. He vomited everything, had great dryness in the mouth, and there was complete anuria. The temperature of the morning was 37·6° C., and of the evening 38·1° C.

May 26.—Patient was now not vomiting so much. There was marked cachexia. He had a feeling of tension in the hepatic region, but percussion of the liver and splenic areas revealed nothing abnormal. Respiration was restricted, causing him to groan. Pulse was small. Temperature was 37·8° C. Total anuria was established.

May 27.—He was now somewhat insensible and apathetic. His voice had become quite hoarse. For the

first time for some days, he had passed a few drops of urine, which, however, consisted mainly of blood. Pulse was now very weak and rapid, the evening temperature being 36·6° C.

May 28.—Patient collapsed and died during the day.

Post-mortem Examination.—The skin was dark-yellow in colour, as were also the substances of brain and liver. The blood of the body was of a profoundly dark colour. The heart-muscle was a little fatty. The gall-bladder was bulging and full of bile. Kidneys were swollen and dark-red in colour, and microscopic examination showed that the tubules were full of red blood-corpuscles.

To the foregoing case are added five others occurring as far back as 1878, due to the same circumstances and cause, which the recorder found incompletely narrated in the hospital journal.

2. B. B., aged forty-four years, along with his brother and others, was engaged from 6 A.M. of the morning of 8th June in filling toy-balloons in the usual way, in a small cellar convenient to a kitchen. The door of the cellar stood wide open during the three hours in which he worked at the operation. In the afternoon, he began to feel ill with pains in the head and epigastrium, which soon became very intense. Toward evening he felt very ill, a yellow colour appeared in his skin, and the urine which he passed had a bloody appearance. On the afternoon of the next day he was admitted into hospital.

His condition on admission was as follows:—The conjunctivæ and skin of body were very yellow in colour; the body was covered with perspiration; and the tongue was coated. Examination of the chest revealed nothing abnormal, although the breathing was quickened and painful. The area of hepatic dulness was small; the spleen could be felt under the edge of the ribs; and the

abdomen was swollen, especially in the upper part, causing a sense of fulness. His urine was intensely blood-coloured. The pulse was small and weak, and the temperature was 39° C. He also suffered from much pain in the head and abdomen, and from great weakness and giddiness.

June 10.—His condition was about the same. He had passed several green-coloured stools. Temperature 38·5° C.

June 11.—He was now somewhat insensible. Since the evening of the 9th there had been absolute anuria. He died at 2 A.M.

Post-mortem Examination.—The dura mater of brain was greyish-red in colour. There was a small quantity of very dark fluid in the pleural cavities and in the pericardium. The heart was flaccid, containing very little dark blood. The endocardium was greyish-red in colour, as was also the mucous membrane of the trachea and bronchi. The liver was swollen and icteric in colour, and the gall-bladder was distended with greenish-black contents. The spleen was swollen and flaccid. The kidneys were also swollen and of a reddish-black colour.

3. G. G. B., aged twenty-eight years, with his brother the preceding patient, had been employed at the same occupation for one hour only. In the afternoon, he took pains in the head and stomach, felt ill, and he observed that the urine which he voided was of a dark-brownish colour. Later, jaundice of the body made its appearance.

He was admitted into hospital on the 10th. On admission, he was seen to have much icteric coloration of the skin and conjunctivæ; the area of hepatic dulness was small; the spleen was enlarged; and the urine had a dark bloody colour. He was vomiting, had pains in the abdomen and head, but his intelligence was perfectly clear. Next day his condition generally was about the

same. The urine, which was scanty in amount, was intensely blood-coloured, and was alkaline in reaction, its sp. gr. being 1,021. Microscopically, it showed broken-down red discs, yellowish-coloured large epithelial cells, and coffin-shaped triple phosphatic crystals. From this date he gradually improved, and was discharged convalescent from hospital on 19th June.

4. G. G., aged twenty-eight years, employed like the others, began to feel ill and giddy on the afternoon of the 9th. By the evening, he had passed bloody urine and had become jaundiced. Being no better next day, he came into hospital exhibiting the same general symptoms as already described, but not so severe. He was dismissed quite well on the 19th June.

5. L. B., aged twenty-two years, was with the others in the cellar assisting at the balloon-filling operation. On the afternoon, he was seized with the same kind of illness as the previous patient, and followed him to hospital. He showed like symptoms, but gradually got better, and left the hospital well on the 27th June. During the course of his illness, however, he had attacks of epistaxis.

6. C. P., aged thirty years. This man did not feel ill until the 11th June, although he had been engaged at same time and place as the others. He was less seriously affected than the others, but had identical general symptoms and was in hospital for nine days only.[1]

Dütting states that these coloured toy-balloons, which are hawked about by pedlars, are filled with hydrogen gas which is generated from a mixture of zinc-filings, water, and sulphuric acid, in an apparatus which consists of a double-necked flask with glass attachments, and that they

[1] It is interesting to note that the cases narrated under Case XII. also occurred in Altona, and were in 1878 treated in the same hospital.

keep one of the attachments ready unscrewed in order easily to introduce additional reagents as required, and from the other the balloons are filled with the gas. Such an arrangement is bound to permit considerable escape of the gas, and should the zinc or acid or both be arseniferous, the escape of hydrogen arsenide.

1888. CASE XXI.—Becker in his inaugural thesis[1] gives the following account of a case.

A healthy, strong man, aged twenty-nine years, who belonged to the merchant class, and who for several years had devoted his spare time to the study of mathematics and Natural Science, while working in a chemical laboratory, felt that he had become ill from symptoms which at first he could ill define. He stated, however, that these consisted chiefly of a dragging pain in the back, and of sudden flashes of light before the eyes. But he gave little heed to them. On the evening of the 14th he again repaired to the laboratory to do some hours' work, but in the course of half an hour he was suddenly seized by violent pains on both sides of the spine which increased to such an insufferable degree that throughout the night he was frequently forced to cry out with pain. Succeeding these pains were repeated shiverings, and next morning there was vomiting of black matter. In the course of the night he passed several stools of a dark bilious appearance. On medical aid being sought, his illness was diagnosed as renal calculus. On the evening of the next day his temperature was found to be subnormal, being 36·8° C., and his pulse to be increased in frequency, but the vomiting had ceased. The urine passed during the night was scanty in quantity, was dark-red in colour, and gave the usual reactions for blood.

[1] *Zur Casuistik der Arsenwasserstoff-Intoxicationen*, Giessen, 1888.

Since the day before he had become drowsy and also quietly delirious, wandering in thought and speech. By this time there was conspicuous brownish coloration of the skin and conjunctivæ, and there was, also, painful enlargement of the liver. During the second night, by reason of threatening symptoms of uræmia, he was sent into hospital.

His condition on admission was as follows:—The skin was of a marked yellowish-brown or bronze colour: there was some degree of anæmia; the mucous membranes of the eyes and mouth were of a yellow colour; his internal organs could not be said to be affected; and his pulse was full, strong, and regular. Examination of the blood showed many "shadow" corpuscles, a few white corpuscles, and much disintegrated product. The liver was enlarged, but the spleen could not be felt below the margin of the ribs. Even in his sleepy state, pressure over the mesogastrium awoke him, as if the pressure pained him. The urine contained much hæmoglobin, and showed microscopically pale shadows of red corpuscles, epithelial casts, and large cells. In the course of the evening, he woke out of this dazed state, and complained of headache, a sense of suffocation, and an inclination to vomit. This did not, however, last long, as half an hour later he relapsed into the former drowsy condition. It was suspected from the profound alteration in the blood-corpuscles that this was a case of poisoning by arseniuretted hydrogen gas or potassium chlorate, notwithstanding the fact that at the time arsenic was not found on examination of the urine. Just then, however, the explanation of the illness was forthcoming. It appeared that he had made experiments with the gas of a balloon and must have inhaled a quantity of the hydrogen gas which had been evolved from zinc and sulphuric acid. Later the same night the

breathing became more difficult, although the frequency of respiration diminished, and by the morning the heart began to fail. Notwithstanding the administration of stimulants, he gradually sank, and died from the combined effects of uræmia and oxygen-starvation. Chemical analysis of the zinc and acid used showed that both contained arsenic markedly.

Post-mortem Examination made twenty-four hours after death.—Body of a strong muscular young man. The skin was of a dark-yellow or coffee colour. There was little post-mortem lividity. The eyelids were puffy and swollen, and the conjunctivæ were yellowish-brown in colour. Even the subcutaneous fat of the body was dark yellowish-brown in colour. The lungs were somewhat collapsed. In the left pleural cavity there was about a quarter of a litre of a brownish-red coloured fluid, and a similar amount in the right cavity. In the pericardium, likewise, was a moderately large amount of a dirty brownish-red fluid. Each of the chambers of the heart contained clots of blood, both ante-mortem and post-mortem in origin. The heart-muscle, especially of the left ventricle, appeared to be somewhat fatty. The spleen was brownish-violet in colour, smooth on the surface, and its capsule was with difficulty stripped from the pulp. The kidneys were enlarged, their capsules being smooth and distended and easily stripped. On section they were found to be dark in colour, the pyramids being sharply defined from the rest of the structure by a dark-brown zone. The urinary bladder was firmly contracted, and contained but a few drops of dark brownish-red urine. In its base was found a granular, yellowish-brown sediment, not unlike altered blood-colouring matter. The liver was enlarged, and its surface smooth and pale; its substance

on section being also in parts distinctly yellowish-brown and brownish-red in colour, giving it a marbled appearance: its consistence was firm. The gall-bladder was filled to distension with very dark, stringy, greenish bile. There was nothing very remarkable in the condition of the stomach. The small intestine contained a very copious amount of dark-greenish bile and masses of chyme. Microscopic examination of the blood showed a disproportionately small number of normal corpuscles, and, on the other hand, a very large number of discs of varied shapes, all more or less pale in colour. Sections of the kidneys, after being hardened in Müller's fluid and osmic acid, showed that the tubules were filled with hyaline and granular casts, and, besides, exhibited evidences of fatty changes.

1889. Case XXII.—For information of the following cases I am indebted to Dr. MacMunn of Wolverhampton. They are peculiar in some respects. They occurred about the year 1889. The men who met with the accident were employed in breaking up zinc-skimmings in a large mortar, resembling a boiler,—a closed receptacle in which a rotatory apparatus was worked by machinery. The process was a patent for the utilisation of galvanisers' flux skimmings, composed of oxychloride of zinc, with 10 to 12 per cent of ammonium chloride, traces of arsenical compounds, and some shots of metallic zinc. Water from an adjacent canal was run into the mortar. The men were cautioned by their employer to add lime to the water before mixing it with the mortar contents, as the canal water was usually acid in reaction. On this occasion, however, they neglected to add the lime, and thus the zinc-skimmings were mixed with water containing acid of an unknown amount. The machinery which worked the mortar got jammed, and one of the men went into

the mortar through a manhole to put it right. What had actually happened was this:—the zinc mass had become clogged in the machinery, and the man tried to break up the mass with an *iron* crowbar or pick, thus setting free the arsenical gas. During this attempt, the man became unconscious in the mortar, and had to be dragged out in this insensible state by a fellow-workman. He remained unconscious until his death, which occurred a day or two later. In the interval, the skin of his body had developed a mahogany colour, and he had hæmorrhages from the nose, bowel, and kidneys. After a post-mortem examination, the organs of the body were examined by Dr. MacMunn, who found the liver and kidneys of a green colour and to contain arsenic. The blood gave the spectrum of reduced hæmoglobin, and the urine, that of met-hæmoglobin. The workman who acted as rescuer also became ill. He passed blood in his urine, vomited blood, and passed blood from the bowel. He recovered, however, after some time.

Analysis of the skimmings showed the following composition:—

Zinc Chloride . . .	41·62
Zinc Oxide	32·53
Ammon. Chloride . .	13·00
Silica	1·15
Iron Oxide	2·15
Tin, Arsenic, Lead	Traces
Water	9·15
	= 100·00.[1]

[1] *An. Report Insp. of Factories*, 1900, p. 465; *Effluvium Nuisances*, Ballard, p. 242.

1891. Case XXIII.—Schickhardt, the narrator of this case, states that during the early afternoon of the 6th, he was hurriedly sent for to visit a chemist, Herr X., who informed him on his arrival that he believed that that morning while working in his laboratory he had been poisoned from the inhalation of a harmful gas. This was not, however, suspected by him at the time. He had been engaged about two hours at the work, and during its progress had several times the desire to vomit, although he had not observed anything else unusual. About dinner time he noticed that he had lost his usual good appetite; nevertheless, he went as usual to his restaurant where he was wont to play a game of chess during his leisure, but he found he was unable to concentrate his thoughts upon the game. On his way home he was seized once with a sudden weakness, and everything began to dance before his eyes. His house being fortunately near at hand, on his arrival there he threw himself upon a couch, becoming for a time unconscious. From this he recovered, but had a second similar seizure later. He complained to Dr. Schickhardt of inclination to vomit; of oppression in the chest; of great weakness and debility; of feeling alarmed, and of being confused in the head and incapable of thinking; of coldness and shivering all over the body; and of a sweetish taste in the mouth: in short, he felt that he was very ill, and began to think he was going to die. His nails of fingers and toes and his eyelids were bluish in colour; the point of his nose was sharpened; the pupils were of medium size and responded to light: the tongue was much coated with fur; the entire body was cold and sticky with perspiration; the action of the heart was very rapid, the pulse numbering 120, and soft and small in quality;

the respiration rate was not substantially altered; he had giddiness and inclination to vomit; and his countenance evinced great anxiety.

Examination of the organs of the chest showed nothing unusual. Schickhardt was of opinion from the foregoing examination that he had to deal with poisoning from inhalation of trade gases which had destroyed a large number of red corpuscles in the blood-stream, from which arose the feeling of oppression in the lungs and the apprehensions of the patient, due to deficiency of oxygen to the tissues.

Later, it came out that Herr X., had been occupied with the reduction of Nitro-methyl-anilin, in which process 1300 grammes of zinc powder were being used along with alcoholic acid. The zinc was analysed, and was found to contain arsenic. He had thus evolved from the mixture arseniuretted hydrogen, from the effects of which he was suffering. It would seem, however, that he had performed the same experiment on previous occasions without any mishap. Doubtless what had contributed to the untoward result on the present occasion was that he worked with all the windows closed in a small room, owing to rough weather outside.

In the course of the afternoon the pressing symptoms became lighter, and the cyanosis disappeared. He complained, however, that he could not hear so well as usual. During the night he was very restless, and had some delirium. Next day he felt a little better. The pulse was full and strong, numbering 100, the temperature 36·5° C. He had headache; the sclerotics were coloured a light-yellow colour; and his urine was scanty and of a dirty brownish-black colour. He complained that he was still unable to think coherently, and his recollection

of the events of the day before had partly disappeared. In the course of the next two or three days, the attacks of shivering, the anxiety, the cyanosis, and the cold sweat disappeared spontaneously. During these days the urine which was passed showed a muddy sediment, evidently originating from the dissolved hæmoglobin. After some days, although he felt comparatively well, he was on several occasions suddenly seized with symptoms of threatened collapse. These attacks were indicated by sudden cyanosis, nausea, chilliness, and small pulse, in consequence of which he was sent to the municipal hospital, where he remained until the tenth day, on which he was permitted to leave.[1]

1892. Case XXIV.—On 23rd August 1892, a man, aged thirty-eight years, who was in charge of a captive balloon in the Tivoli Gardens, Copenhagen, set about mending a breach which had been made in the dome of the balloon, and from which the gas had escaped. After doing this, he filled afresh the balloon with hydrogen gas which he generated from iron filings and sulphuric acid. From the effects of this operation he became ill, and exhibited the following symptoms, viz.:—giddiness, headache, nausea, and cardialgia. At night he could not sleep, and the urine which he passed was very bloody and of a black colour. These symptoms he himself attributed to the balloon gas. On analysis of the acid used, it was found to contain 0·11 per cent of arsenic.

Examination of the patient showed that he was clear in intelligence, and was in good spirits; his temperature was 38·4° C.; the pulse 72, somewhat dicrotic; the skin was moist and coloured of a peculiar deep brownish-red tint: and the conjunctivæ were of an intensely muddy

[1] *Münchener med. Wochenschrift*, xxxviii. 26, 1891.

brownish-red tint. In the evening he had much headache, cardialgia, and weakness, but no vomiting; temperature was 38·6° C.; the urine was dark, blackish-red in colour, copious in amount, with a sp. gr. 1,032. On standing, it presented a plentiful, granular, brownish-red sediment, which under the microscope showed numerous granules, but no red corpuscles or tube-casts.

Aug. 24.—His condition was unchanged, except that the headache was somewhat better, and he had partaken freely of milk and water. The urine was still blood-red, its sp. gr. 1,027. The pulse numbered 102, and the temperature was 37·9° C.

Aug. 25.—Condition was somewhat improved, but he still felt very dispirited, and was made irritable by the sounds of the street traffic. The urine was now abundant, and was clearer.

Aug. 26.—No enlargement of hepatic or splenic areas could be detected. The urine was still blood-coloured, sp. gr. 1,011, and contained 0·7 per cent of albumin. The skin was lighter, perhaps, in colour, although the jaundice was still markedly yellow.

Aug. 27-31.—During these days his condition slowly improved; the urine and the jaundice both becoming lighter in colour.

Aug. 31 till *Sept.* 4.—Improvement continued. On the latter date, for the first time since his illness, he expressed himself as having an appetite. By 22nd September he was convalescent.[1]

[1] Storch, *Verhandlungen des Congresses für Innere Medicin*, 1892, p. 176.

CONDITIONS OF URINE DURING ILLNESS.

Date.	Sp. Gr.	Albumin.	Hæmoglobin.
Aug. 23 .	1032	—	5·95
,, 24 .	1027	—	3·83
,, 25 .	1018	—	1·28
,, 26 .	1013	0·7	Traces
,, 27 .	1012	0·5	Do.
,, 28 .	1010	Traces	None
,, 29 .	1009	None	Do.
,, 30 .	1010	Do.	Do.

Note.—The sign (—) signifies that no estimate was made.

1892. CASE XXV.—Three men in a work in Llanelly were engaged in dissolving a mixture of metals in an open tube with hydrochloric acid. Two of them became seriously ill, the third not so seriously. One who was exposed to the gaseous fumes from the process for only ten to fifteen minutes was seized six hours afterwards with diarrhœa and severe pains in the abdomen. The following day he became jaundiced. By the sixth day he appeared to be a little better, but he died suddenly on the seventh day, paralysis of the limbs having supervened shortly before death. The second suffered from a like train of symptoms, and died on the tenth day. The third recovered. The metals were proved on analysis to contain the following, viz. :—

Silver	8·4 per cent
Zinc	4·0 „ „
Arsenic	0·8 „ „
Copper	0·8 „ „
Antimony. . . .	traces

The gases liberated, therefore, contained the hydrogen gases

of both arsenic and antimony; consequently, the signs of poisoning were mixed.[1]

1892. Case XXVI.—In a Danish journal a case is narrated by Schleisner.[2] It would seem to differ only from those already recorded in that the cause is simply set down to impure hydrogen.

1893. Case XXVII.—J. G., a foreman in a chemical work, was engaged on the 22nd November, between 3.30 and 4 P.M., in the manufacture of zinc chloride by dissolving zinc with commercial hydrochloric acid. During the time he was so employed he wore a muzzle over his mouth and nose. The proportion of acid to zinc used was ten carboys of the one to half a ton of the other. Arrangements which existed within the works for carrying away by means of a draught apparatus fumes generated as on the present occasion were not employed by him. At the end of the operation he felt very ill, and he vomited. Thinking himself "gassed" (as the workmen term it), he took half a pound of treacle—a supposed workman's remedy,—and, later, went home, dressed himself, and set out for a walk, from which, however, he had quickly to return and go to bed. By this time he had pains in the head, stomach, and across his loins. The urine which he passed was very dark in colour. He was unable to get sleep during the night on account of the incessant vomiting.

Next day his conjunctivæ and skin were deep-yellow in colour; temperature and respiration were normal; the amount of urine voided from 4 P.M. of the previous day equalled about 20 ounces, was dark in colour, opaque, and looked like blood; his countenance was dusky yellow, but

[1] *Public Health*, vol. iv., 1892, p. 317.

[2] *Forgifting med. uren. Brint. Ugesk. f. Laeger*, Kjøbenhavn, 1892, 4 R. xxv. pp. 243-249.

not pinched. There was incessant vomiting. The pulse was 120 and irregular.

Nov. 24.—Urine passed since previous day amounted to two ounces; vomiting was still persistent; hiccough was very severe, and very troublesome at times; he had great thirst; pulse was 102 and irregular; temperature was 98·8° F.

Nov. 25.—He was still much jaundiced. He had passed one and a half ounces of urine since the previous night, which was dark in colour. Vomiting persisted. He had twitchings in the muscles of the right forearm. Pulse was 90, but more irregular, and the temperature was 98° F.

Nov. 26.—He had had a fair night and had slept at short intervals for short periods. He had had a motion from the bowels of a dark slate-colour, which was liquid. No urine had been passed. Pulse was 104 and irregular, the temperature normal. By the evening he had passed about 3 ounces of urine.

Nov. 27.—Improvement was maintained. Urine passed was orange-coloured, and contained albumin. Jaundice was less marked. There was marked muscular debility on getting out of bed. Hiccough had ceased. Pulse was 110, but still irregular. He was very drowsy.

Nov. 28.—He had slept most of the night; had two very dark liquid stools; had voided urine on two occasions amounting in all to about one and a half ounces, which was bile-stained, and contained one-fifth albumin. He had twice vomited fluids taken during the night, the vomit consisting of dark-coloured matter. He died suddenly at 3.30 P.M., when attempting to get out of bed.

Examination of Urine.—It was dark in colour and was apparently composed chiefly of blood. It contained no

shreds or coagula, but portions coagulated on boiling and on addition of acid. Microscopically it contained broken-down red blood-corpuscles, and spectroscopically it gave the spectrum of hæmoglobin. It was also found to contain arsenic.

Examination of the blood of the patient taken from his arm on the 25th showed a few broken-down red discs, no rouleaux, and a want of definition of the edges of the remaining corpuscular elements. Analysis of the acid used by Reinsch's and Marsh's processes showed that it contained "freely" of arsenic, and that the zinc contained traces. No post-mortem examination of the body was permitted.[1]

1895. Case XXVIII.—In the latter part of 1892 (November) Dr. Hans Schulze, professor of chemistry in the University of Santiago, met his death by the inhalation of this gas. The red corpuscles in his case were found to be diminished in number to 1,800,000 per cubic millimetre, instead of about five millions which is the normal figure. Progressive anæmia supervened, and he died on the fifth day. On post-mortem examination of the body, the tissues were found in a state of fatty degeneration.[2] We regret that the details of this case, as above recorded, are so meagre, as from the details which are given it would appear as if the symptoms had been carefully observed and recorded. In neither of the references which we have given is there any reference to the original record of the case, and we have not been able to trace it.

1895. Case XXIX.—Strassmann[3] has recorded the following case. A workman, named S——, was employed for four days in an anilin manufactory where hydrochloric

[1] Martin, *Medical Chronicle*, vol. xix. p. 108, 1893-94.

[2] Luff, *Text-book of Forensic Medicine and Toxicology*, vol. i. p. 168; Binz, *Lectures on Pharmacology*, vol. ii. p. 94 (Syd. Soc.), 1897.

[3] *Lehrbuch der gerichtlichen Medicin*, p. 423.

acid was being used. On 9th February he had to leave work because he did not feel quite well. Three to four hours later, his medical attendant found him cyanosed, jaundiced, and with some œdema of the eyes. He had vomited once, and had passed about two litres of dark-red urine. There was no apnœa, the pulse was strong and full, and he was quite clear in intellect. Next day he was sent into hospital, but by this time he was in a state of stupor. His skin was mulatto-coloured. His temperature was 38·3° C. On physical examination the area of hepatic dulness was found to be increased; and the urine which he passed was like "Nürnberger beer." The following night he was delirious, and vomited bilious matter, which was repeated many times during the next day or two, in spite of the morphia which was administered to him. The temperature afterwards became normal, but the stupor remained, the pupils not responding to stimuli. Anuria supervened, catheterism proving the bladder to be empty. He died on the 12th. The blood was not examined during life.

Post-mortem Examination.—The skin and mucous membranes were of a greyish-yellow colour. Of the internal organs, the bowels and bladder were grey in colour, the kidneys, heart, lungs, and liver being more brownish. The spectrum of the blood was that of oxy-hæmoglobin and met-hæmoglobin. Microscopic examination showed the red discs to be of a serrated or crenated form. The tubules of the kidneys were filled by blood-casts. Chemical examination of the materials used showed the presence of arsenic.

1895. Case XXX.—The following cases are recorded in the inaugural thesis of Ernest Lucas.[1] The thesis deals with the general question of poisoning by this gas, and

[1] *De l'Empoisonnement par l'Hydrogène Arsénié*, Paris, 1895.

several of the cases which we have already taken from their original sources are therein quoted, while, at the same time, many others have not been noticed. For those who may desire to consult this thesis, it may be well to state that the author treats the subject under the following heads, viz. :—(1) History; (2) General Considerations; (3) Symptomatology; (4) Experiences and Pathological Anatomy; (5) Pathological Physiology; (6) Arseniuretted Hydrogen and Occupational Hygiene; and (7) Treatment. The cases which he gives are as follow :—

1. On 1st February 1893, M. Duguet, a student of pharmacy and assistant in chemistry at the School of Medicine of Poitiers, aged twenty-one years, and of good previous health, was working in the court of the laboratory in the preparation of this arsenical gas. This was about 10 A.M. Desirous of knowing if the gas had begun to come off, he took the notion to smell at the apparatus in order to recognise its odour. The gas was being evolved in abundance. Although he knew that it was a very poisonous gas, he took no special care, thinking that the quantity which he had sniffed was insufficient in amount to do him any harm: so he quietly continued his work. After some minutes' interval, he wished again to perceive if the odour of garlic, characteristic of the gas, was present. But he noticed that he had complete anosmia. He thereupon called to his aid M. Caillaud, a fellow-student, and asked him to discover if the gas which was being evolved was certainly arseniuretted hydrogen. His friend approached the apparatus, but he hardly took time to take an inspiration from the point of the evolving-tube, since strongly convinced of the presence of the gas by the disagreeable odour which he perceived, he drew back quickly. He nevertheless took ill, as shall be narrated. As for M. Duguet, he

remained in the vicinity of the apparatus for about three and a half hours afterwards, and he estimated that he had respired but a small quantity. Five minutes after the commencement of the experiment, however, he already began to feel a very intense headache, which continued to get worse: but he was far from associating it with its true cause. Soon thereafter, vertigo accompanied by buzzing in the ears, vague uneasiness, and a feeling of great weakness supervened. Having just returned from the fêtes at Bordeaux, to which he had been delegated by his fellow-students, M. Duguet attributed his symptoms to the fatigue of his journey. In the meantime his countenance changed rapidly, his complexion becoming exceedingly pale, and his eyes brilliant. He felt his legs bend under him, and he had a burning thirst. At 11.30 he went to the restaurant where he was in the habit of taking his meals. His appetite had not completely disappeared, but deglutition was so painful that he felt compelled to stop eating after the first mouthful. He felt the bolus pass uncomfortably down the whole length of the gullet. It appeared to him, indeed, as he himself expressed it, "that the mouthfuls scraped the backbone." It was only at this moment that he apprehended that he was poisoned. He thereupon set out without assistance to the medical director of the School, who advised him to return home as quickly as he could, and, without waiting, to take magnesia hydrate. He went into a pharmacy on his way and took a glass of magnesia, which immediately produced vomiting. It was now about 12.30 P.M. Still unaccompanied, he resumed his way home, but he could no longer feel his feet, and his legs stole from under him. He staggered like a drunk man, and was obliged to lean along the walls of the houses to prevent himself from falling. Although the

weather was somewhat cold, it seemed to him insupportably so, as his teeth chattered. By 1 P.M., he was in bed. Immediately thereafter, a great shivering, comparable to that which ushers in pneumonia, came on. Clothes were heaped over him and hot-water bottles put to his feet, but in spite of all an hour elapsed before these measures succeeded in restoring heat to him. At 2 P.M. his skin began to burn, followed by abundant perspiration, although his extremities still remained cold. He was plunged in deep prostration, but his mind was quite clear, as it, indeed, remained throughout the whole course of his illness. Dr. Christian, who saw him at 3.30 P.M., found him in the state above described. Auscultation revealed nothing abnormal in lungs or heart. Percussion showed that there was enlargement of the liver and splenic areas, but not to any marked degree. The pulse was small but regular, and numbered 85; the temperature was normal. The lumbar region was painful both initially and on pressure, and the epigastric region, and that of the liver, painful solely on palpation. Towards 4 P.M., patient who had not micturated since 9 A.M., now passed two spoonfuls of a blackish liquid. He complained that the pains in the loins were becoming more and more violent, and, in addition, he had now vague pains in his joints. He was not able to retain any nourishment, although he only vomited when he partook of anything. He was given morphia subcutaneously and had troublous sleep for three hours thereafter. From 9.30 P.M. till 3 A.M., he passed on three separate occasions, with pain and much effort, urine which amounted in all to between 40 and 50 c.c., its colour being black. It was found to contain much albumin and hæmoglobin. At 3 A.M., he fell into a quiet, natural sleep, which lasted till 6 A.M.

Feb. 2.—His condition was less and less satisfactory, his prostration being accentuated. Enlargement of liver and spleen was now quite marked. The pulse was 78, and there was no fever. The only fluid which he was able to retain was lemonade, even milk being rejected. He passed during the course of the day from 60 to 80 c.c. of urine, which was still black in colour. At 5 P.M., a light-coloured jaundice began to appear, which soon became more marked; at the same time, the tint of the jaundice was not that ordinarily seen, being somewhat bronze-like or brownish in hue.

Feb. 3.—Inhalations of oxygen were prescribed, but they did not seem to produce any discernible effect, although the patient expressed himself as feeling better after their use. The urine was a little more abundant, being 250 c.c. in amount, and it was less black, being more of a red colour. Its analysis showed much albumin, and spectroscopically it gave the spectrum of hæmoglobin.

Feb. 4.—He had passed a relatively quiet night, the vomiting not occurring so frequently. The amount of urine was as the last, and it was becoming more reddish in colour.

Feb. 5.—The lumbar pains were less; the urine was hardly so red, contained less albumin, and the blood-colouring matter formerly present had now given place to bile pigments. Oxygen inhalations and baths and other treatment were continued as before.

Feb. 6.—The urine now amounted to 500 c.c., was more clear, but albumin was still present.

Feb. 7.—His general condition had improved: he had voided about one litre of urine; jaundice was still marked; liver and spleen were both still enlarged.

Feb. 9-11.—Improvement continued; pains had ceased;

he was able to take some nourishment; jaundice was diminishing.

Feb. 12-13.—He had now commenced to sit up in bed, although he felt giddy and became subject to cardiac palpitation on the least effort.

Feb. 14.—He was lifted out of bed and placed on a couch, and although yet extremely weak, his state was reckoned to be very satisfactory. There was now polyuria.

Feb. 18.—He was now sufficiently well to be sent home to his friends. Jaundice was only slightly noticeable in the sclerotics. After a stay of a month at home, he was able to return to his studies. His urine, however, remained albuminous for five months afterwards.

2. M. Caillaud, fellow-student of the former patient, aged twenty-two years, inhaled but a small quantity of the gas under the circumstances already narrated. An hour later, having gone home, he began to experience slight illness, the symptoms of which were pains in the head, not sufficiently severe, however, to compel attention under ordinary circumstances, and a desire for micturition. The urine which he voided, he observed, was like blood. Although this perplexed him, feeling as he did but little incommoded otherwise, he went as usual to the restaurant at 11.30 A.M. where he took his meals. When there, however, other symptoms developed. These were shiverings, noises in the ears, giddiness, sickness, and pains in the loins. He was not able to touch the food placed before him. He went home, which took him a good quarter of an hour,—a distance which in ordinary circumstances took only five minutes. His gait was very unsteady, and, as he himself said, he was very glad to make use of his walking-stick to maintain his equilibrium. He went to bed at

once. The shiverings, which were limited in degree to light repeated chills, ceased almost immediately thereafter, giving place to a gentle perspiration. Dr. Christian saw him after leaving the former patient, and on examination found nothing abnormal on percussion or palpation, nor any fever. The pains in the loins were quite violent, but the coldness of the extremities was not marked. The amount of urine was almost normal, was, however, of a blood-red colour, and was albuminous. It contained hæmoglobin. During next day the hæmoglobin had almost disappeared, but urobilin was present. He had never vomited. On the evening of the second day jaundice made its appearance. After the third day, the symptoms began to abate, and the urine to look more normal. On the fifth day the jaundice disappeared in its turn, and he was able to get out of bed. He was treated exactly as his fellow-student.

The following third case recorded by Lucas was reported to him :—

3. In 1890, Dr. Jolyet, professor of chemistry in the Faculty of Medicine of Bordeaux, was estimating in one of his lectures the respiratory capacity of the lungs by Grehant's method. To this end, he inhaled hydrogen gas, in which, unknown to him, was this arsenical gaseous impurity. At the end of the lecture he was seized with violent headache, giddiness, flashes of light before the eyes, tingling of the ears, and sickness. A great feeling of tiredness and general weakness ensued, and walking became almost impossible. The urine was of a blood-red colour. He was jaundiced. Cure rapidly followed the inhalation of oxygen. The sulphuric acid used to generate the hydrogen was found, on analysis, to contain arsenic, although sold as pure acid.

1895. Case XXXI.—One of the most important contributions on the subject of poisoning by the gas now under discussion is the joint production of Professor Dixon Mann and Dr. Clegg.[1] Not only does it include an interesting series of cases, but an effort has been made within the compass of an article to a medical magazine to epitomise the work of others on the subject. The series recorded by these authors embraces five new cases which arose in the manufacture of zinc chloride by dissolving in a large vat metallic zinc with hydrochloric acid. The particulars of the cases are as follow :—

1. F., aged about fifty-two years, had been occasionally working at this process for some time before he took ill. He began to work for the last time prior to his attack on 27th March, and continued daily till the evening of the 29th. On that day he left for home at the usual hour, complaining of pain in the back. The same night he began to vomit, and this continued more or less during the two following days. At first the vomit contained clotted blood. He passed red urine at first, but after noon of the 31st, anuria prevailed. His skin was of a dusky hue, and his conjunctivæ were injected and yellow. He began to ramble in his speech on 2nd April, was quite delirious toward the end, and died in the evening of 4th April, after an illness of six days.

Post-mortem examination :—

External.—There were two oval patches of discoloration on each side of the abdomen. The lips were somewhat livid. There was a dark-blue line on the margin of the gums.

Internal.—Brain was anæmic, but otherwise normal. *Thorax.*—The pericardium contained about three ounces of fluid which was coloured as if stained with bile. All

[1] *Medical Chronicle*, vol. iii. (New Series), p. 161.

the cavities of the heart contained clots, greater or smaller in size, and of ante-mortem and post-mortem origin. The pleuræ contained a small quantity of fluid like that in the pericardium, and the visceral and parietal pleuræ were of a deeper violet colour than usual. Both lungs were emphysematous at their apices, and congested and œdematous at their bases. The bronchial mucous membrane was slightly reddened. *Abdomen.*—A blue coloration was present over the whole of the intestines, this being of a very deep blue over the anterior portion of the lower surface of the liver, especially on the right side. The omentum, also, was of a bluish colour. The mucous membrane of the stomach appeared gelatinous on its surface, and showed a large number of petechiæ. The inner surface of the upper end of the small intestine was likewise gelatinous in appearance, and was more or less congested along its whole length, especially so in the first ten feet. For three feet above the ileo-cæcal valve, ecchymoses were present, and marked congestion a foot above the valve. The large intestine was stained of a deep bluish-green colour. The liver was large, firm on section, and normal in colour. The gall-bladder was full. The spleen was normal in size, firm, and deeply congested, its capsule not easily stripped, and its serous covering blue in colour. The right kidney was firm, very much swollen, its capsule non-adherent, and a small patch of bluish discoloration was present on the lower part of its anterior surface. On section, its substance was dark-red in colour, the pyramids showing blue-black patches in the central parts. The left was like the right. The urinary bladder contained half a dram of fluid which was tinged with blood-colouring matter. On microscopic examination, kidney epithelium, fatty casts, and large corpuscles were found, and chemically, albumin and bile-pigment.

2. R., aged fifty years, worked at the vats on the 26th, and again on the 29th, from morning till 5.30 P.M., when he left for home feeling unwell. He vomited before leaving the works. When seen next morning he complained of pain over the liver and in the epigastrium, as well as of deep-seated pain in the back. He had vomited both bile and blood, and had had several stools consisting, at first, of fæces and blood-clots, and later of bile and blood, accompanied by tenesmus. He was jaundiced, the skin being of an ashy dusky colour, and the conjunctivæ of a yellow colour. He had tenderness over the liver region, and the pain in the back lasted till the evening of the 31st. He was very restless during the whole illness, and his friends as well as himself declared that he had never passed any urine. On 1st April a catheter was passed, and about one dram of blood-stained urine was drawn off. He had dryness of the throat and thirst, and there was dyspnœa for two days. He died on 5th April, and was delirious before that event.

Post-mortem examination, made thirty-three hours after death :—

External.—Hypostasis of the face was much as usual, except that on the ears and posterior half of the cheeks it was of a very deep blue colour. On the gums, especially of the lower jaw, there was a broadish blue line.

Internal.—Head.—Brain and coverings were normal. *Thorax.*—The pericardium contained one and a half ounces of fluid. The heart was somewhat enlarged, its cavities in respect of contained coagula being much as in the previous case. There was a small quantity of fluid in each pleural cavity. Both lungs were œdematous and congested. *Abdomen.*—The stomach was deeply congested, and petechiæ were present over its whole mucous surface. There was less gelatinous softening of the mucous membrane

of the small intestine than in the former case. The liver was somewhat enlarged, its surface was smooth, and on section, its tissue was firm in consistence and normal in colour. The spleen was very deeply congested, its substance friable, and its capsule difficult to strip. The right kidney was swollen and rounded, its capsule non-adherent. On section, deep congestion of the whole organ was apparent, and the pyramids were of a bluish-black colour. The left kidney was like the other, except that the pyramids were not so deeply coloured. The urinary bladder was contracted and empty. Microscopic examination of tissue of liver showed that the cells were swollen and cloudy, but the nuclei could be stained with logwood. There was no appreciable bile-staining. With osmic acid staining irregular areas of fatty degeneration were seen, containing particles of fat which were stained black. No deposit of iron was discovered in the liver by treating the tissue with potassium ferrocyanide and hydrochloric acid. Sections of the spleen exhibited extensive congestion and slight fatty degeneration of some of the cells. In the kidney the glomeruli were swollen, and filled their capsules; in some places there was detachment of the epithelium lining Bowman's capsules, and in other glomeruli there was slight proliferation of the epithelial cells. In some tubules the epithelial cells had partially, and in others had wholly, disappeared. Some tubules were choked with shed cells and granular débris, and in others the epithelial cells had proliferated. Much of the granular débris consisted of blood-colouring matter. The epithelial cells themselves were in many instances swollen and cloudy, and were in various stages of detachment and disorganisation, showing granules which had stained black with osmic acid. The blood-vessels were very congested, and there was some

slight cirrhosis of old standing. The spleen showed extremely marked congestion, and some of the cells showed slight fatty degeneration.

3. Another workman, aged thirty years, commenced to work at the process on 3rd April. He turned ill that same night with malaise and the passing of dark-coloured urine, along with pain in the back. Next day, when seen, he still complained of the pain in the back, and he was voiding porter-like urine. He was weak, anæmic, and jaundiced. The number of corpuscles in the blood as counted on 7th April was found to be 1,800,000 per cubic millimetre, and the amount of colouring matter to vary in different corpuscles. On 4th April the urine was found to contain albumin. That which was passed on the 5th had a sp. gr. of 1,022, its reaction was alkaline, its colour black like porter, and when diluted with four volumes of water, red in colour, like blood and water mixed. The spectrum of the blood in the urine was that of oxy-hæmoglobin. Bile-pigment was present, but no bile-acids. The albumin amounted to 0·66 per cent, and the urea to 1·4 per cent. Microscopically, the urine showed epithelial cells, chiefly of kidney origin, epithelial casts, large exudation cells, a few red discs, and granular fatty matter. There was no inorganic deposit. There was no albumin in the urine of 7th and 8th April. That of the 9th gave the spectrum of met-hæmoglobin, and the microscopic appearances were those already described. By 11th April, the urine was again quite clear. He recovered.

4. Another workman did the same work as the others on 3rd April. He took ill that afternoon after filling the vats. His symptoms were like those of the last man. On 7th April his red corpuscles numbered 2,700,000 per cubic millimetre. The urine passed on the third day was reddish-

brown in colour, acid in reaction, and had a sp. gr. of 1,025. The spectrum of acid hæmatin was obtained, and on adding ammonium sulphide, that of reduced hæmatin. A small amount of bile-pigment was present, but no bile-acids were found. The albumin amounted to 0·11 per cent, and the urea to 2·7 per cent. The copious deposit in the urine consisted of amorphous urates, débris of red corpuscles, epithelium, chiefly renal, undergoing fatty changes, large corpuscles, along with large and small casts, fatty and hyaline, in large numbers. The urine passed three days later was lighter in colour, yielded the spectrum of methæmoglobin, was free from bile-pigment and bile-acids, and, microscopically, conformed to the sample before described.

5. Another workman who was employed in the same work but who was not working at the process, took ill on the night of 29th March. About noon of that day he gave a hand to help to lift a vessel about the size of a beer barrel which had just been charged with zinc and acid, and which had no cover or lid on it. This took him only a few minutes, after which he resumed his ordinary duties for the day. About 7 P.M., he returned to close a window over the vats, which also took him but a minute or two, when he again returned to his own duty until 8 P.M., the usual stopping hour. At 10 P.M., he felt queer, and began to vomit. He had also pains in the epigastric region which lasted very violently all that night. At midnight he passed very dark urine. Next day he had some pain in the back, but he had no more vomiting. Jaundice showed itself on the 30th, and had not quite disappeared on 11th April, by which date the urine had become perfectly clear.

Chemical examination of the viscera of the fatal cases gave the following results:—

Case 1.—Arsenic was found in the liver, kidneys, bile, urine, and blood, and also in the fluids from the pleural cavities and pericardium. In the liver only was the amount sufficient to enable a quantitative determination to be made, and for the entire viscus it equalled 0·002 gramme of arsenious acid.

Case 2.—Arsenic was found in the liver, kidneys, and spleen. In 37 c.c. of blood and serum not a trace could be found. From the liver the amount for the entire organ equalled 0·0016 gramme of arsenious acid. An unsuccessful attempt was made to ascertain the presence of the gas (AsH_3) in the tissues by distilling the blood in vacuo, but no trace of the gas could be found.

1898. CASE XXXII.—The case recorded by Gulewitsch[1] was that of a man who dipped a copper and zinc plate into a mixture containing arsenious acid, sulphuric acid, hydrochloric acid, and water. He was manager of a bronze foundry. His main symptoms were:—polyuria, hæmoglobinuria, albuminuria (one per cent), and urobilinuria. Bile-pigment and bile-acids were not found in the urine. These symptoms appeared about one hour after exposure to the fumes from the above operation. The history of the case was briefly as follows:—The day before admission into hospital, 6th October 1897, he was working with the above mixture, and he practically took ill at the time. Two litres of urine which he passed on 8th October were submitted to examination with the following result, viz.:—It was smoky in appearance, but there was not much deposit. After destruction of the organic matter with potassium chlorate and hydrochloric acid, warming, and treating with H_2S in the usual way, it was subjected to Marsh's process, and gave evidence of the presence of

[1] *Zeitschrift für physiologische Chemie*, 1898, vol. xxiv. p. 511.

arsenic, not, however, large in amount. By 2nd December, the urine was normal in appearance, although on that day he passed three litres. He completely recovered.

1901. CASE XXXIII.—The facts relating to the next series of ten cases were forwarded to me by the kindness of Dr. Clayton, who published an account of them later.[1] The men were employed in the manufacture of zinc chloride from crude zinc oxide and hydrochloric acid, the oxide being a waste product from the process of galvanising iron. The acid was made in the works in which the mishap took place, and admittedly contained arsenic acid, which was presumed to amount to not more than 0·1 per cent, although this particular batch of acid was not analysed. The zinc also contained arsenic, but in less amount. Although the employers stated that to their knowledge no other cases of this kind had previously occurred in their works, Dr. Clayton is of opinion, from information which he possesses, that cases had happened before, but of a milder character.

The following is a short description of the surroundings of the workmen while carrying out this work:—At one end of a platform measuring six yards by four yards, and raised about four feet from the ground, stood a vat about five feet square. From this platform, and at the opposite end and five yards from the vat, was a gangway running to the ground level. Both platform and vat were in the open, as was also the ground to which the gangway runs; with this exception, however, that over the ground portion and about fifteen feet above it, was a sloping roof about three feet wide, which sloped from the wall of a building outside which this process was conducted. The sloping roof afforded some shelter from rain to the men working

[1] *Brit. Med. Journ.* vol. i., 1901, p. 392.

beneath. This part, which was a sort of well, was therefore open to the air, with the exception of having the platform in front and the sloping roof above it. The object of conducting this process in the open was that the fumes produced might more readily be carried away from the working place. Leading from this well was a doorway into the building through which material was brought for feeding the vats, and about ten to fifteen yards distant and inside the building was a furnace. The acid was caused to flow directly into the vat from a cistern in the adjacent building by means of a trough. The zinc oxide was emptied from bags into the vat by hand. These bags were brought from the ground-level up the gangway to the vat by other men. On the occasion under consideration, it would appear that the men for some reason were eager to get through a certain amount of work by noon, and two or three extra hands were taken on. The vat was kept well going, and more fumes than usual may have been evolved. The day was warm and unusually sultry. The fumes could not get away. The crude zinc oxide had probably mixed with it a small quantity of carbonate from which CO_2 would be evolved, hence, in addition to absence of natural movement of air, by reason of the greater gravity or density this gas and the AsH_3 would tend to fall groundward. In addition to these natural forces, there would undoubtedly be no little indraught exerted by the furnace inside the building through the open doorway. Instead of the access to the air being a security, it actually constituted a danger on this occasion. As a matter of fact the men who were working nearest to the vat on the platform and above the ground-level of the well suffered the least, while those down below on the ground-level of the well suffered the most. Of the three men working on

the platform two were attacked. One was severely poisoned, one slightly, and the third escaped entirely. Four men were engaged shovelling the zinc oxide from a cart on to the ground in the well, and were at no time within ten yards of the vat, yet all of them suffered severely. There were three others who were occupied in loading barrows from the zinc oxide heap on the ground and conveying it up the gangway to the vicinity of the vat. These also were poisoned severely, one of these dying from the effects of poisoning on the seventh day thereafter.

The symptoms exhibited by these men may be summarised in the history of the following cases of the series:—

The case of the foreman who was engaged in emptying bags into the vat, and who was the most severely affected of those who were working at the vat, may first be considered. He was a robust, powerful man, and had been engaged at this particular work for sixteen years. He had been at work all the morning of the day of the attack, and left the work at 2 P.M. Half an hour later he felt sick, nauseated, and depressed, with a hot, burning pain from throat to stomach, and with an intense thirst. These symptoms were soon followed by violent vomiting, at first of food, then of everything as soon as swallowed, even of iced water. This in turn was succeeded by an equally severe diarrhœa, the discharges at first being composed of loose fæcal matter, then rice-watery in character, and finally containing blood. Added to these was hæmoglobinuria, with a rapidly developing jaundice, which within twenty-four hours assumed an intense coppery hue. The feeling of depression deepened into extreme prostration, the facial features becoming sunk and cyanosed, the pulse thready, and the voice lost. These severe symptoms lasted with

gradually diminishing severity for several days. The feeling of prostration, the anæmia, and the almost pale green colour of the skin which supervened on the disappearance of the jaundice, lasted for several weeks longer; and it was only after the lapse of five weeks that he was able to return to work.

In the single fatal case of the series, the symptoms showed no variation from the foregoing, excepting that there was suppression of urine; and after thirty-six hours of complete unconsciousness, the man died on the seventh day.

In all the cases there was jaundice. In eight of them it was intense, and in the remaining two it could only be described as slight. In nine of the cases there was hæmoglobinuria or hæmaturia. Intense thirst and a burning pain in the chest characterised the onset and the earlier stages of all the cases. Diarrhœa was troublesome in five of the cases, and all, with the single exception referred to, suffered from profound anæmia in the later stages of the disease. The effect on the nervous system was more or less severe in nine of the cases, and in six of these the prostration and collapse in the earlier stage were very severe. One man who was engaged with these ten others, and who was on the platform nearly the whole time, escaped without any symptoms whatever; and the varying degrees in which the others were affected would seem to indicate that individually they had inhaled different amounts of the gas, or else that individual susceptibility played some part, which, however, is very unlikely. The man who died could not be said to be a good life, as he had been a heavy drinker.

1899. Case XXXIV.—Maljean[1] has pointed out the

[1] *Archives de Médecine et de Pharmacie militaires*, 1900, xxxv. 82-102.

following instances of military persons who have been attacked poisonously by this gas in connection with the inflation or deflation of military balloons. During the months of May and June 1899, Maljean had an opportunity of observing among aeronauts and those employed about balloons several cases of sudden illness in which jaundice was the prominent and unusual symptom. He did not recognise the true character of the illness in the first two cases, but a little later it became possible to establish proof that the cause was poisoning by arseniuretted hydrogen. His cases fall under three groups.

1. A corporal in a company of aeronauts, strong and of usual good health, was being employed on 16th May 1899, in inflating a balloon. He remained from 8 A.M. till 4 P.M. in the inflating shed. He was also in charge during the night along with three other men. This shed was spacious, and was entirely open on each of its large sides. Nevertheless during the process, a garlicky odour, characteristic of balloon gas, made itself felt around during the whole forenoon. At 6 P.M. he began to feel unwell; he was giddy, and had pains in the head; his urine became black like strong coffee. He ate nothing that night or on the following morning. At 11 A.M. of the 17th he went to bed, his neighbours noticing that he had become yellow in colour. His temperature was 37·5° C. On the 18th, he entered the infirmary, because of the jaundice. His conjunctivæ and the whole surface of the body presented a uniform yellowish tint, inclining towards green. His general state was good; appetite had, however, disappeared; tongue showed a thin whitish coating, which did not extend to the margins. During the first two days he had a little diarrhœa. The urine, which was black the night before, now showed a deep mahogany colour, without greenish

reflections. Palpation of the liver and of the epigastric region revealed no swelling or enlargement, and evoked no pain. His pulse, a little feeble, varied between 84 and 96; there was apyrexia; no itching of skin; there was no xanthopsy. He slept well during the night, and continued drowsy during the day. The jaundice lasted four days. The treatment consisted of milk diet and diluent drinks. He returned to duty on the twelfth day, although he remained pale and somewhat feeble for about a month.

2. M. C., lieutenant, of usual good health, was directing the filling of the same balloon. He remained for a little time in the shed, but on several occasions he went to the nozzle of the gas afferent-pipe and sniffed thereat in order to discover by the odour if the hydrogen had displaced the air in the pipe. That was the common way of testing the arrival of the gas at the nozzle. He remembered later that he had respired or sniffed the gas three or four different times, and on each occasion for about ten seconds, the total period in all being about forty seconds. About mid-day of the 16th May, that is, some hours after he had sniffed the gas, he began to feel ill, with sickness, great lassitude, and general weakness. Towards evening, his urine became black, and he had some diarrhœic stools accompanied by colic. This colour of urine continued the next day. He was seen by Maljean on the second day of his illness, the 19th. The jaundice was much more marked in his case than that of the corporal, the tint being deeper, and inclining to olive-green. His conjunctivæ shared the same colour, which differed appreciably from the yellow aspect of common jaundice. His urine was now not so black as at first; it had a brown mahogany hue. Pulse was 94; there was apyrexia; but there was no swelling or pain over the margin of the liver. The

tongue was whitish in the middle, and his appetite was feeble. He was treated like the previous patient. The jaundice began to disappear on the fourth day. Although incompletely restored to health, he returned to duty at the end of six days.

3. A month later, this same officer was again poisoned, but under different circumstances. On the 24th June he set out early in the morning on a free balloon ascent. The balloon descended about 3 P.M. in Burgundy. During the deflation of the balloon, which took place in the middle of a field, he stood at the appendix or tail of the balloon, and accidentally inhaled a certain quantity of the escaping gas: indeed, his voice assumed the special tone which characterises sounds emitted in an atmosphere of hydrogen, that medium being less dense and a poorer conductor of sound than air. He did not feel incommoded at first. He took the train for home at 7 P.M., and slept during the journey. Towards 10 P.M., illness began by sickness, vomiting, and colicky pains followed by diarrhœa. His urine became black and scanty. Next day, 25th June, jaundice appeared; his illness continued; he remained in bed in a drowsy condition; his mouth was clammy, and his breath had a garlicky odour. On the 26th, the diarrhœa ceased; his tongue was whitish in the middle, but red at the edges. Jaundice, very intense, showed itself of the same greenish-yellow colour as in his first illness. The urine continued black in colour, and small in amount. He had a dull pain in the lumbar region, which disappeared for short intervals, and it was not made worse by palpation; there was general lassitude; but there were no shiverings. The axillary temperature was 37·6° C.; pulse was 88, and small; there was no itching of the skin; and there was no pain in the region of the liver.

Chemical examination of the urine gave the following results:—quantity small, and neutral in reaction; it was coffee-coloured, reddish by reflected light; it left on his underclothing stains analogous to stains of blood. There was a slight deposit of mucus. It had a saline, but not a bitter taste. It had no odour, and it was not frothy. Heat and acids produced an abundant precipitate of albumin. Shaken in a test-tube with chloroform, it showed a scarlet-red colour; the chloroform at the bottom of the tube remaining absolutely colourless. The subacetate of lead gave a precipitate of a brownish-red colour. Gmelin's test and Pettenkofer's test showed the absence of biliary pigments.

Microscopic examination showed the following:—(*a*) a large number of renal casts, some epithelial, others granular; other casts were full of decolorised red blood-corpuscles: (*b*) many epithelial cells from the kidney, the pelvis, and the ureters; these were either single or were united in strips of two or three together: (*c*) some free red blood-corpuscles, most of which were decolorised and not indicating the double contour; they appeared as pale discs in the midst of a coloration uniformly yellow like urine. Some discs, very small in number, had preserved their colouring matter and their normal appearance: (*d*) some polynuclear leucocytes: and (*e*) some amorphous fragments of material having an ochreous colour, some isolated, others included within the casts.

The urine was examined to see if it contained arsenic, and by Marsh's process it gave in abundance the characteristic rings of metallic arsenic. In short, the urine contained an enormous amount of hæmoglobin, and no biliary pigments, and there were found in it the elements characteristic of acute nephritis, and a certain amount

of arsenic. The relatively small number of intact red blood-corpuscles showed it not to be hæmaturia, but hæmoglobinuria.

June 27.—The condition of the patient remained the same.

June 28.—There was some improvement: the jaundice had not changed; the lumbar pain had diminished; the feeling of lassitude and of drowsiness persisted, however, much the same. There were anorexia, a condition of nausea, some reddish-coloured stools, liquid in consistency, apyrexia, and a pulse numbering 100. The greatest change perceptible was in the urine, which still scanty, had lost its black colour, and presented a deep brown tint. It was still slightly acid, and contained much albumin. Placed in a conical glass, it left a blood-coloured deposit which contained the same histological elements as before.

June 29.—Jaundice began to disappear; strength and appetite began to return; the lassitude was less marked; the lumbar pain persisted; the pulse had fallen to 84. The patient, who had been on purely milk diet up till now, began to eat some solid food. The urine remained scanty, however, was acid in reaction, and less highly coloured. Acetic acid precipitated a little mucus. The albumin had much diminished. The deposit still contained renal elements, but in smaller numbers.

June 30.—The lumbar pain had disappeared; the skin began to resume its normal colour; the conjunctivæ remained a little greenish in colour; the pulse was now strong, and numbered 94. The urine, still coloured, did not contain so much albumin, but only some mucin and some epithelial elements.

July 1.—The jaundice had quite disappeared; pulse

was 84; he had a good appetite. The urine had resumed its normal quantity, but gave, when allowed to settle in a glass, a thin floating cloudiness, normal in appearance, and there was no albumin.

The patient, though pale and sensibly thinner, returned to part duty. He was given the usual diet, with phosphate of iron. He had lost 5 lbs. in weight. He was well at the end of a month.

Case XXXV.—In addition to the cases which he had himself observed, Maljean reports other cases of which he had been informed by others.

Two cases occurred at Arras in a company of aeronauts. An officer and a sergeant were occupied in the operation of inflating a balloon. At different times they sniffed the afferent gas-tube as in the previous cases, having the same object in view. Some hours after, both felt violently ill, with giddiness, great lassitude, and loss of appetite. Next day, they were attacked with very pronounced greenish-coloured jaundice, and their urine became scanty in amount and black like coffee in colour. The illness in the case of the officer lasted four days, and that of the sergeant, five days. Notwithstanding the rapidity of the recovery, the officer found that he had lost about 5 lbs. in weight.

Maljean had information also of several facts of a like kind which had been observed in another military establishment, in which men had been attacked by illness of which jaundice and black urine were the prominent symptoms, which left no doubt of the cause of the illness. Moreover, he was informed by an officer that his special service or duty exposed him to vague illnesses, of which headache, lassitude, and anorexia were the chief symptoms. He observed that these supervened

whenever he was engaged in inflating or deflating balloons, or was engaged in free ascents. On leaving his balloon he felt more fatigued than his exertions warranted. When he was a day off duty, he became well again. Maljean was of opinion that these illnesses could not be attributed to exposure to rarefied atmospheres, because in military ballooning such altitudes were not attained. Besides, the illnesses in question came on after every ascension in which the officer had assisted in the preparatory operations. Maljean believed that the attacks were due to inhalation of impure hydrogen.

1900. CASE XXXVI.—Crone[1] records the facts connected with the attacks, symptoms, and deaths of two soldiers who were employed in filling a balloon with hydrogen gas. They had on previous occasions been employed at this duty, but on the occasion in question the pipe from which the generated gas was issuing was not screwed into the corresponding orifice in the balloon, and had even been adapted to a part of the balloon where the entering gas was confined, and thus it flowed out as fast as it went in, and so enveloped the men causing them to respire it. They did not perceive their mistake until the end of twenty minutes. The effects which were produced on them were giddiness and a sense of constriction in the head, which, however, particularly the latter, disappeared soon after they had removed themselves away from the balloon. They experienced, besides, dyspnœa, and creepy sensations over the whole body. Their skin became coloured of a brownish-red or brownish-yellow colour; the conjunctivæ were injected; they showed much agitation; and their temperature was 39° C.

[1] *Deutsche militärärztliche Zeitschr.* 1900, 3, p. 139.

They also complained of pains throughout their bodies, especially in the chest and back. Later, they began to have vomiting of a bilious character, and on the second day of the attack, abundant diarrhœa set in. They showed oliguria; and the urine was found to contain sulphurous and arsenical derivatives. By the third day, the vomiting was almost incessant, the diarrhœa profuse, and faintings with clonic cramps developed. There was almost complete anuria. The pulse was feeble and quickened, the temperature being only 38° C., the respiration became irregular, the heart began to fail, and they both died, one on the third day, and the other on the fifth day after the accident.

The treatment employed consisted of tepid baths, cooling drinks, and injections of physiological saline fluid. Although the symptoms seemed at first to be ameliorated by this treatment, the intoxication seemed to be too profound to be successfully combated by it.

Post-mortem examinations having been conducted on the bodies, the following were the principal facts observed: —great anæmia of the organs; the left heart and the vessels contained some thin, elongated, blackish-coloured clots; the right heart showed more numerous clots of the same characters; there was œdema of the bases of the lungs; the kidneys were congested; the liver was hypertrophied or enlarged, being yellowish in colour, and was like the tissue of fatty kidney. Otherwise, there was nothing particular to note.

Analysis of the stomach, of the heart, of the kidneys, and of the blood individually by Marsh's process gave evidence of the presence of arsenic. The reaction for the arsenical gas could even be obtained from the hydrogen gas used in filling the balloon, as well as from the iron

and the sulphuric acid which had been used to generate the hydrogen.

Crone declares that the excessive toxicity of the arsenical gas is demonstrated by the fact that these men, although working in the open air, and in spite of the early treatment of their attacks, died from the effects of its inhalation.

1900. CASE XXXVII. — Granjux[1] gives another instance of a similar attack which occurred in the balloon-park of Chalais-Meudon, which led to the death of the victim.

From *Le Temps* of 8th April 1900, the following facts relative to the above are narrated as follows :—Some men were engaged in inflating and deflating balloons, when, an escape of gas occurring, two sappers were taken seriously ill, and succumbed in a semi-asphyxiated condition. Help was quickly at hand. The balloon was repaired and the work recommenced. A new escape developed, and three sappers fell. One of these, named Hérard, unhappily died some moments after. These two men, along with their comrades previously attacked, were taken to be treated; but shortly after, the regimental surgeon considered the state of the men to be grave enough to compel their transference to the military hospital at Versailles. A second death occurred on the 14th April. An enquiry was opened regarding the cause of the accidents, and it was believed that the hydrogen was impure. It contained traces of arsenic.

1889-90. CASE XXXVIII. — Oulmont[2] gives an account of two cases of fatal poisoning with this gas, also arising from the inflation of balloons. The first case was

[1] *Bulletin médical*, 14ème avril 1900.
[2] *Méd. mod.* 1889-90, i. 933-935.

that of a young man who was attacked during an ascension. He was sitting under the escape valve, when, the balloon becoming distended by alteration of atmospheric pressure, caused the gas to escape by the valve. The second case was that of a peasant who respired the escaping gas while assisting to bring a balloon to earth.

1900. Case XXXIX.—In the *New York Medical Record* another case of poisoning by the gas is recorded.[1]

1901. Case XL.—Three Italian pedlars were poisoned in Breslau in 1901 while employed in filling children's toy-balloons with hydrogen which was being generated from zinc and sulphuric acid. The exact conditions were not, however, established, yet the interesting point which emerged was that the acid which they were using most likely contained arsenic, as it was well known that sulphuric acid was being sold in that city which contained 0·6 per cent of arsenious acid. The only reference which we have been able to find of these cases is that from which the above sparse facts have been taken.[2]

[1] *N. Y. Medical Record*, 1900, lvii. 1097. It is quite possible that Case XXXIX. is identical with Case XXXVII., as the facts given in the American Journal are most indefinite.

[2] *Zeit. f. angew. Chemie*, 1901, p. 766.

CHAPTER XIII.

CASES OBSERVED BY THE AUTHOR.

THE following cases occurred in a process of industry, in which, like many of the cases already narrated, arsenic was not only no essential part of the process, but was actually an impurity of an otherwise comparatively innocuous trade substance. So far as the writer knows, they are the first cases to have been recorded from this particular chemical operation.

CASE XLI.—The facts of the first case are as follow:—

W. E., aged twenty-nine, married, whose family history was free of any hereditary taint of disease, and whose father and mother, brothers and sisters, were all alive and well, and whose personal health history had been unvaryingly good, and whose habits, moreover, were temperate, left his former employment, which was that of loading vessels in port, about six weeks before, to become a worker in a chemical work in which bleaching-powder was one of the products of manufacture. The history of his attack and illness is summarised as follow:—About 6 A.M., on Friday morning, 30th March 1900, he went to work as usual, his first duty that morning being to clean out a chlorine "still" or retort of the refuse which it contained, and which was called by the men "manganese mud."

After putting on his "muzzle," he descended by means of a manhole in the top of the still to its bottom, and

proceeded to fill a zinc-galvanised iron pail with the semi-liquid or pultaceous, greenish-coloured deposit or débris with an ordinary broad iron shovel. After having been in the retort for what seemed to him to be about ten minutes, he felt sick and called for the ladder to be let down by which he might re-ascend and get out of the retort. On reaching the open air, he vomited; and the sickness continuing, he went to the "bothy," a little house used by the workmen, and there sat down by the fire till between 8 and 9 A.M., feeling sick and ill all the time. He thought he had got "gas," by which he meant to say that he had inhaled a quantity of chlorine gas. He observed, however, a peculiar sweetish taste in his mouth, which was unusual in the case of chlorine. This taste he had perceived on previous occasions when performing the same operation, but on these it was neither so pronounced nor so persistent. While he had had sickness on these occasions also to a slight degree, it did not last for any length of time. Assisted by his brother, he left the works for home at 9 A.M., and went to bed. At that time he passed about half a pint of dark-coloured urine, resembling in colour Condy's fluid. His usual medical attendant, Dr. P., was called about 10 A.M., who found him very sick and vomiting every few minutes a dark-greenish fluid in large quantities, which had an intensely bitter taste. His temperature was 98·4° F., and his pulse 78. He complained of pain in the region of the stomach and liver, but percussion of the hepatic region indicated nothing abnormal. The descending colon was not empty, but his bowels had moved that morning before he started work. The lungs and heart were found on examination to be acting normally. He was given morphia and atropia hypodermically in combination. At 5 P.M. there was no

change in his condition, but he had had short intervals of sleep. He was now, however, slightly jaundiced. There was suppression of urine. Pilocarpin nitrate was administered hypodermically without effect, except, perhaps, to increase the sickness and to lower the pulse-rate.

March 31.—His temperature was now 97·6° F., and the pulse 70, full and strong. The conjunctivæ and skin of entire body were now intensely jaundiced of a deep orange colour. Vomiting still continued persistent in spite of the administration of iced soda-water, and the use of counter-irritation over the epigastric region. The pain in stomach and liver, especially over the region of the gall-bladder, was very acute, and was increased on pressure. Hyoscyamine hydrobromate, given hypodermically, relieved the pain, and temporarily checked the vomiting. In the forenoon, a consultation was held with a neighbouring practitioner, when it was agreed to repeat the pilocarpin. When repeated, however, it produced such depression that it was deemed unwarrantable to continue it.

April 1.—There was no material change in the general symptoms, but the base of the left lung had become somewhat dull on percussion. By reason of the unusual character and train of symptoms, and the absence of signs of improvement, a consultation was again held with a third practitioner, who confirmed the presence of the lung condition and recommended the use of turpentine stupes to base of lungs and whole lumbar region. Patient was seen several times during the day, and hypodermic injections of hyoscyamine were given at intervals when pain became acute. His condition otherwise was the same.

April 2.—Our connection with the case began on this date, having been called in consultation. Up till this

time no name had been given to the disease, and no suspicion as to its precise causation had been aroused, further than that it was probably associated with the incident in the retort at the works. The condition of the patient was then as follows:—The skin generally was of a marked coppery hue, and differed distinctly from the yellow colour of ordinary jaundice. He had constant hiccough, vomited at short intervals, and complained of soreness over abdomen generally, which latter, however, appeared to us after examination to be due to the constant spasmodic contraction of the abdominal muscles from the hiccough and vomiting and not to peritonitis. He complained further of pain in the loins, and he had a cough, which was, however, neither severe nor frequent. On examination of the chest we were not able to discover any specific or definite lung lesion. He had passed no urine since the morning of the 29th ult. Percussion of the bladder region indicated that there was no distension, and led to the view that if that viscus did contain urine it could be but little in amount. To settle the question, it was agreed that the catheter should be employed. He was prescribed Sanitas fluid, ℥.xv., every two hours, which was well borne. This was prescribed because it contains free hydrogen peroxide, and also because of the view at which we had arrived that the illness was due to inhalation of a poisonous gas which had acted rapidly and profoundly upon the blood, and had thus interfered with its oxygen-carrying power; besides the Sanitas was easy to get. In the evening the bowels were cleared by an enema. The vomiting and hiccough ceased, and he had had four to five hours of quiet sleep, from which he awoke much refreshed. Shortly after waking, however, he again vomited, the vomit consisting of "coffee-grounds-like'

material. The jaundice appeared less intense in the skin, but was unchanged in the conjunctivæ. The temperature was 97° F., and the pulse 80. The bladder had been emptied by catheter and was found to contain one and three-quarter ounces. It was very dark in colour, and was as dark as that passed a few hours after the seizure. The urine was forwarded to us for examination.

April 3.—The vomiting was not so frequent, but the matter vomited was still dark-brown in colour. Patient was now much weaker, but did not now suffer from pain. Temperature was 97° F., and the pulse 82. The evening temperature rose to 98° F. He was placed in a hot wet pack in order to encourage free action of the skin.

April 4.—He had slept fairly well through the night, and once for three hours at a stretch. He was very weak and depressed, but was without pain. At 5 P.M., the temperature was found to have fallen to 96·8° F. Warm saline solution was injected hypodermically between scapulæ and into the gluteal regions. Hiccough was now practically continuous.

April 5.—At 2.30 A.M., he was found by his medical attendant to be quiet, to be able to reply intelligently to questions, urging the doctor at the same time to do all he could for him. The vomiting had entirely ceased for over nine hours, and the hiccough had also stopped. When he was left alone, it was noticed that he lapsed into a wandering delirium, but if asked what was wrong, he replied he was giddy. His hands, feet, and head were found to be very cold, even when his body was enveloped in a hot wet pack. His temperature was now 96° F. Half an ounce of brandy was given to him, the vessel containing it being conveyed to his mouth by himself. Half an hour later, he died peacefully.

A post-mortem examination of the body was made, with consent of his relatives, on the following day by an experienced pathologist, Dr. Lindsay Steven, who reported of the examination as follows:—

The body was that of a man fairly well developed, of about thirty years of age. The face presented a dull coppery hue, and there was a slightly yellowish tinge of the skin generally. Rigor mortis was moderately present, and decomposition was commencing in the abdominal wall.

Chest Cavity. — The pericardium presented healthy characters. The left ventricle of the heart was slightly hypertrophied, but otherwise the organ presented quite healthy appearances. All the valvular structures were normal. There was no visible appearance of fatty degeneration of the heart-muscle, and the external fat was not increased in amount. The lungs were non-adherent, and the pleural cavities were normal. Both lungs were slightly emphysematous along their anterior margins, and both were the seat of well-marked hypostatic engorgement and œdema, but otherwise they were healthy in appearance. The bronchial tubes and the lower part of the trachea were especially examined, but they presented no signs of active congestion or of catarrh.

Abdominal Cavity.—The stomach was of normal size, and was empty. Its mucous membrane exhibited a slaty-grey colour, probably the result of commencing decomposition, but was otherwise quite healthy in appearance. The lower part of the gullet was also healthy. The intestines showed a dark-greenish colour throughout, partly the result of decomposition and partly due to staining with bile. The gall-bladder was distended, and slight pressure upon it caused an abundant flow of bile, dark and thick, through the duodenal papilla into the

intestine. The ileum and ascending colon contained a moderate amount of normally-coloured fæculent matter. Peyer's patches presented healthy appearances and were easily seen. The mucous membrane of the intestines seemed normal throughout. The liver was normal in size, or, perhaps, slightly enlarged. Its surface was smooth, and its colour was normal both externally and on section, the cut surfaces looking quite healthy. Spleen seemed normal. Both kidneys were slightly enlarged and of a dark-red colour. The capsules stripped easily, leaving a perfectly smooth surface. On section, the cortex and pyramids were found to be sharply demarcated, and beyond the dark-red colour, the result of engorgement with blood, presented no abnormal appearance. The naked-eye appearances of the blood called for no particular remark.

Head Cavity.—The *dura mater* was healthy. The brain also, both externally and on dissection, presented quite healthy appearances throughout.

Portions of the internal organs were retained for further examination and analysis.

Microscopic examination of the blood showed a broken-down condition of the red corpuscles.

Portions of the liver, kidney, heart, lung, intestine, and brain were also submitted, after sectioning, to a like examination, with the following results:—Generally speaking, the minute structure of the tissues of these organs exhibited healthy appearances. In the liver and kidney, however, and to a less extent in the heart and intestine, pigmentary changes of some importance were noted. In the liver, granular deposits of brown-coloured pigment were seen in the hepatic cells, particularly those in the vicinity of the hepatic vein. Such deposits undoubtedly indicated that destruction of red blood-corpuscles had

occurred during life. In the kidney, heart, and intestine, granules of black pigment were seen in the interior of several of the blood-vessels, and in some parts also, in the perivascular tissues.

The urine which had been drawn off by catheter was examined by us with the following result:—It measured one and three-quarter ounces, and was of a dark-bloody colour. Microscopically it showed a few broken-down red corpuscles, tube-casts, and amorphous matter, and gave freely the chemical and spectroscopic reactions for blood. When treated by Reinsch's process, traces of arsenic were found.

CHAPTER XIV.

CASES OBSERVED BY AUTHOR, ETC. (*Continued*).

It will be of interest to discuss briefly the cause of the illness of the unfortunate man which has been described in the preceding chapter. The somewhat anomalous character and course of the symptoms were at first undoubtedly puzzling to those who were called to treat this patient in the early stages of his attack, and it was because of the development of the suspicion that the illness was somehow associated with an obscure form of poisoning that our services were enlisted. When we saw the patient, had carefully examined him, and had considered his symptoms, the conviction that it was due to a gaseous poison was forced on our mind. At first, and before an opportunity had arisen of enquiring into the nature of the chemical process, we were inclined to think of phosphuretted hydrogen or an allied hydrogen gas as the cause; but phosphuretted hydrogen was at once put out of court on enquiry, and the conclusion was arrived at that arseniuretted hydrogen was the cause. In the meantime, the medical attendant had certified the death as due to "toxæmic jaundice." As soon, however, as our opinion was conveyed to the local officials who administer certain provisions of the Factory Acts, a report was made to the Home Office, whereupon the medical inspector, Dr. Legge, came down to the district and pursued enquiries. In the

course of these he procured from the chemical works in question certain samples of the acid used in the process and of the débris left in the retort with which the man was dealing when overtaken by his illness. He was also put in possession of the portions of the organs retained from the post-mortem examination of the body.

The Chemical Process.—Our enquiries in the works relating to the process employed in the retort, and to the operation at which the deceased was occupied when taken ill, showed the following important points:—The Welldon's still or retort was part of the invention of Welldon for the generation of the chlorine gas needed in the manufacture of bleaching-powder. Into this retort before commencing the process of making this product are placed definite large amounts of (*a*) crude hydrochloric acid, and (*b*) manganites of calcium and manganese, mixed. The account which is given, after fuller investigation by Dr. Legge of the process, and particularly of the chemical ingredients put into the retort or still, is as follows:—"The Welldon mud 'acid calcium manganite,' a mixture of manganites of calcium and manganese, is run into the still which is filled to a height of two feet with hydrochloric acid. After the chlorine has been evolved, the manganese chloride liquor is withdrawn, but a certain amount of residue remains behind consisting partly of calcium sulphate which has to be removed by entering the still."[1] It would appear that the crude acid above named was made in the works in the following way. By roasting Spanish pyrites which is composed mainly of copper and iron sulphides, sulphuric acid is manufactured, and from this crude sulphuric acid acting upon common salt, the crude hydrochloric acid was produced. By the well-known action of manganese

[1] *An. Report of Chief Inspector of Factories*, 1900, p. 460.

dioxide on hydrochloric acid in the presence of heat chlorine gas is liberated, which, saturating freshly-slaked lime, forms bleaching-powder. During the currency of the process of manufacture of this powder, fresh charges of the above-named chemicals are put into the retort at stated intervals of three hours, so that the manufacture of the powder may go on continuously. The process is conducted continuously, by night and day, for about three weeks at a time, the effect of which is to cause the collection of débris from the process in the retort, which at the end of each period of working has to be removed by hand by workmen. It will be remembered that it was while so engaged that this man was seized with illness. It now remains to describe the retort. This is an octagonal structure, composed of slabs of stone, and measures ten feet in height and about eleven feet in diameter. It has a small opening at the bottom and a larger opening in the roof or vault. Both of these are closed tightly while the process of manufacture is proceeding. When, however, the retort has to be cleaned out, the following preliminary steps must be taken before the retort is in a condition, because of the chlorine gas which lingers in it, to be cleaned. First of all, the retort must be permitted to cool. It is then opened at top and bottom to let air in. When the run-out pipe or opening at the bottom of the retort, which is about four inches above the level of the floor of the retort and of about four inches in diameter, is opened, all the fluid in the retort above its exit level flows out, but all matter, fluid and semi-solid, below that level remains within. Thereafter, these openings top and bottom being patent for some hours, the nozzle of a steam-pipe is passed into the bottom opening, and steam is blown through the retort for three or four or more hours. After the retort

has cooled down from the effects of the steaming, the workman is permitted, his air-passages covered with a "muzzle," to enter it for the purpose of removing the sediment which yet remains at its bottom. The muzzle consists of a number of layers of flannel cloth, and in practice covers the mouth only, the idea being that the wearer should inspire by the mouth and expire by the nostrils. It is intended to guard against the irritating effects of any chlorine gas which may yet linger in the retort.

The workman enters the retort by the opening in its roof or vault, and descends to its floor by means of a ladder, and thus removes the débris. The apparatus which was used consisted of an ordinary broad iron shovel and a zinc-galvanised iron pail, and as the pail is filled it is handed to a second workman stationed on the roof of the retort, who empties it and returns it to the workman inside. This débris or sediment which remains in the retort at the end of the three or four weeks' spell of continuous working amounts to about twenty to thirty cwts. in weight, and usually forms a layer of about six inches or more in depth on the floor of the retort. It consists of the following ingredients, viz.:—(*a*) manganese chloride and unacted-on manganese dioxide, and (*b*) any excess of hydrochloric acid, assuming for the moment that the chemicals when introduced are pure. But bearing in mind that the hydrochloric acid in use was made from crude sulphuric acid manufactured from Spanish pyrites, and that this ore is apt to be peculiarly rich in arsenical compounds, such as arsenious and arsenic sulphides, it is not difficult to conceive that the débris must also contain arsenic. As a matter of fact, it was acknowledged in the evidence of the works chemist given at the public enquiry

held later by the Sheriff under the Fatal Accidents Enquiry (Scotland) Act, that the pyrites used in the works contained about the average amount of arsenic.

As has already been noted, samples of the débris were obtained by Dr. Legge, and were submitted to analysis by Dr. Thomas (now Sir Thomas) Stevenson of London, a report of the examination of which was as follows:—The deposit consisted of a yellow liquid with a grey sediment or deposit, the latter amounting to two-thirds of the whole. The liquid portion consisted of a solution of impure chlorides of manganese and calcium, had a sp. gr. of 1,179, and contained arsenic in the form of arsenic acid. The sediment was composed of a mixture of impure calcium sulphate and grit.

Composition of Deposit.	Parts per Cent.	Grains per Gallon.
Arsenic Acid (H_3AsO_4) . .	0·45	315
(Arsenicum)	0·24	168
Hydrochloric Acid . .	7·61	5,327
Uncombined Chlorine . .	0·03	21
Ferrous (proto) Salts . .	None	None
Ferric Chloride . . .	0·17	119

The sample of crude hydrochloric acid was found to have the following physical appearances and chemical composition:—The colour was yellow, and its specific gravity 1,165. It contained arsenic in the form of arsenious acid (As_2O_3).

Composition of Hydrochloric Acid.

Substance.	Parts per Cent.	Grains per Gallon.
Arsenious Acid . . .	0·292	204·4
(Arsenicum)	0·221	154·7
Hydrochloric Acid . . .	31·021	21,714·7
Uncombined Chlorine . .	0·042	29·4
Ferrous Salts	None	None
Ferric Chloride . . .	0·005	3·5
Sodium Sulphate . . .	Traces	Traces
Water	68·640	48,048·0
	100·000	70,000·0

From the foregoing analyses, it is obvious that the acid used in the process was highly arsenical, and as was to be expected, the sediment in the retort also contained a considerable amount of that substance. It would appear, moreover, that the acid contained more arsenic than the average acids of commerce. If we compare the foregoing figure for arsenic with those given by Lunge[1] on p. 6, we shall be able to institute comparisons. In the Belston Cases (p. 200) the acid only showed 0·035 per cent of arsenic, whereas in Dixon Mann's Cases (p. 158), it contained 0·309 per cent.

In these circumstances, arsenic being present in the débris to the amount of 0·45 per cent, we can easily see by the aid of chemical equations how arseniuretted hydrogen was bound to be generated within the retort whenever materials as an iron shovel and a zinc-galvanised iron pail were used by the workmen. The bulk of the arsenic is retained in the débris but is there present in the form of arsenic acid, having been oxidised into that form by the agency of the chlorine gas. When, therefore, the

[1] *Sulphuric Acid and Alkali*, vol. ii. p. 180.

débris was shovelled into the zinc pail, the following chemical reactions occurred, viz. :—

$$4Zn + 8HCl + H_3AsO_4 = 4ZnCl_2 + 4H_2O + AsH_3.$$
$$4Fe + 8HCl + H_3AsO_4 = 4FeCl_2 + 4H_2O + AsH_3.$$

When the arsenic present exists in the arsenious form, the reactions are :—

$$3Zn + 6HCl + H_3AsO_3 = 3ZnCl_2 + 3H_2O + AsH_3.$$
$$3Fe + 6HCl + H_3AsO_3 = 3FeCl_2 + 3H_2O + AsH_3.$$

Sir Thomas Stevenson experimented with the liquid portion of the débris from the retort in question by immersing in it, first, iron and zinc separately, and second, both metals together. In both sets of experiments hydrogen and arseniuretted hydrogen gases were given off. Similar experiments with the crude acid produced the same results.

What is the precise form or forms in which the arsenic exists in the retort-débris, is a question regarding the answer to which there may be differences of opinion. It is well known that if arsenious acid is ignited in contact with pure, dry chlorine gas, the compound $AsCl_3$, the so-called butter of arsenic or caustic oil of arsenic, is formed. This is a colourless oily-looking liquid, which evaporates in the air at ordinary temperatures, giving off white fumes which, in the presence of moisture, are composed of arsenious oxide (As_2O_3) and hydrochloric acid; but should the quantity of moisture be insufficient for complete reaction, the fumes are composed of oxychloride of arsenic or chlorarsenious acid, AsClO, or $AsCl_3.As_2O_3$. It may be taken from the foregoing analysis of the sediment from the retort that the arsenic existed in an arsenic state, probably partly united with some of the chlorine which is returned in the report as uncombined.

It will hardly be possible, except approximately, to arrive at the exact total quantity of arsenic present in the retort at the time this unfortunate man entered it to clean it out, by reason of absence of knowledge of the total quantity of acid used over the entire period of three to four weeks. The works authorities are of opinion that the amount by weight of the débris was between 25 and 30 cwts. On the assumption that it was the lower of these two weights, and that according to analysis the arsenic present in terms of arsenious acid was 0·317 per cent, a little calculation will show that the total amount of arsenic in terms of arsenious acid existent in the débris was about nine pounds in weight. This fact is only of significance, however, in showing that Marsh's process, unconsciously set in operation by the workman, was easy of accomplishment, and that the gas evolved during the operation of handling the débris could be, and was, serious in amount.

The portions of internal organs which were removed from the body of the deceased were also submitted to analysis by the same authority; and the following are the main points of interest relative thereto in his report. The viscera were placed unfortunately in formalin (40 per cent formaldehyde) and were retained in that medium from 6th April till 1st May, when they were placed in the hands of the analyst. They consisted of portions of all the internal organs of varying weights, their total weight, however, being then eleven and a half ounces. It was estimated by Sir Thomas Stevenson that the above weight would represent at least twenty-four ounces of fresh viscera. The liquid in which the portions of organs were immersed contained at the end of the time of immersion an amount of arsenic equal to $\frac{1}{2000}$th of a grain of

arsenicum or 0·00066 of a grain of arsenious acid. The combined weight of the viscera themselves contained $\frac{1}{5}\frac{1}{0}$th of a grain of arsenicum or 0·0037 of a grain of arsenious acid. If we assume that the deceased was a man of average weight, viz.:—150 lbs., which he was believed to be, and that the poison was uniformly distributed throughout the body, which was not unlikely since it was a gaseous poison, then the whole body would contain 0·28 of a grain of arsenicum or 0·37 of a grain of arsenious acid. The question arose as to whether the formalin was arsenic-free. Apart from the fact that formalin is usually free from arsenic, it is quite clear from the amounts found in the formalin fluid and in the viscera respectively, that it was the formalin that was tainted by the poison from the viscera, and not the viscera from the formalin. The total amount of arsenic reported as the likely equivalent of the poison in this man's body was 0·37 of a grain in terms of arsenious acid. But it may relevantly be remarked, why was not the sum of both of these amounts of arsenic in formalin and viscera returned as the total amount present in the man's body? It would seem, by excluding the proportion found in the formalin, as if the analyst did not desire to magnify the amount of arsenic found. At the same time, the obvious effect of this is to depreciate sensibly the ultimate calculation of the total bodily amount of arsenic. There is another factor, besides, which must affect that total, and one which is also subject to difference of opinion, viz.:—the proper relation in weight between viscera which have been treated in formalin, and those which have been untreated; in other words, what is the depreciation in weight which viscera treated by formalin for some weeks undergo? It will have been noted that the weight of

viscera, as they were received for analysis, was eleven and a half ounces, and that it was estimated that that weight would correspond to twenty-four ounces of fresh viscera. This is one of the questions about which there might be reasonably difference of opinion: but it is a question of some importance in such a case as this whether the shrinkage in weight of viscera from formalin immersion is as great as fully 50 per cent. Our experience is that the shrinkage is not so great. If we assume, for example, that the eleven and a half ounces of formalised viscera were the equivalent in weight of eighteen, rather than twenty-four ounces of fresh viscera, the resulting total of arsenic in the body would become about one-third larger in amount. The previous calculation, based on the equivalent of eleven and a half ounces of formalised viscera to twenty-four ounces of fresh viscera, on equal diffusion of the gaseous poison throughout the body, and on the body-weight being 150 lbs., worked out, as already shown, as 0·37 of a grain of arsenious acid. This, it will be noted, did not include the arsenic found in the formalin in which the viscera were preserved. If, however, that figure found in the formalin fluid be deemed an integral part of the original amount of arsenic which these portions of organs contained, and if it be added to the 0·37, the total amount of arsenious acid found in the body would work out as 0·436 of a grain. If, now, the calculation be worked out on the basis of eleven and a half ounces of formalised viscera being the equivalent of eighteen ounces of fresh viscera, the other factors remaining as above, the figure for total arsenic in the body would come out as 0·58 of a grain of arsenious acid. It may, therefore, be taken that the truth lies somewhere between the two figures, viz.:—0·436 and 0·58 of a grain.

The point, however, which emerges clearly from the analysis of the body of the deceased man is that it contained arsenic to an estimable amount. But this must not be looked upon as the total lethal amount which killed the man; indeed it is only a portion of the original quantity, but what that exact quantity was it is impossible to tell. That the total amount was reduced may be safely argued from the fact that he lived for nearly six days after respiring the gas. The amount of arseniuretted hydrogen equivalent to the quantity of arsenic found in the body may be calculated. If we take the larger of the two amounts which emerged from the previous calculations, viz.:—0·58 grain of arsenious acid, we have a basis from which a calculation may be made. This 0·58 grain of As_2O_3 is equal to 0·439 grain arsenicum, and will produce 0·452 grain of arseniuretted hydrogen. Since one litre, or 61·027 cubic inches, of AsH_3 gas weighs 3·4944 grammes at standard temperature and pressure, one cubic inch will be equivalent to 0·882 grain of AsH_3; therefore, the quantity of arsenic found in the body in this case will be equal to about one-half a cubic inch of pure AsH_3.

When the conditions under which this man was placed when he received the fatal dose of the gas are reviewed, we shall discover reasons for the likelihood of occurrence of poisoning. The place in which he was working was, in the first place, a very confined space, inasmuch as the openings in it were only four inches and two feet in diameter respectively, and although the former was near the foot, and the latter in the roof or vault of the retort, there was practically little or no through current of air. There certainly was no free ventilation. Nor was there any danger to a workman from the retort or its contents

at the time of entrance; but the danger did begin as soon as he proceeded to dig out the débris with the implements he was using, since he then began to generate the arsenical gas. It can be imagined that if during this cleaning operation sufficiently large openings had existed near the floor and at the roof of the retort, and if free currents of fresh air had been blown through at the time, the gas might have been so diluted as to be practically free from danger to life. But under the circumstances, no such free ventilation existed, no such dilution was produced, and the unfortunate workman inhaled the gas in a somewhat concentrated form, and thus were produced the symptoms and result already noted. The danger from such an occupation as this arises from the workman generating unwittingly the poisonous gas by his own act; therefore in all similar cases in which arseniferous acid or chemicals are to be so dealt with, metal implements ought never to be permitted to be used. The danger may be entirely removed, as was advised in this case, by the use of wooden implements and wooden, leather, or compressed paper pulp buckets.

A second employee was also affected on the same occasion, but with temporary ill results only. H. M. entered the same retort after the former workman was compelled to leave it, and he completed the cleaning process. He was engaged in the retort for from twenty minutes to half an hour, but that period was divided into three separate spells of work. He, like the former, experienced the sweet taste in the mouth, and on coming out of the retort the second time, also became sick and inclined to vomit, but did not actually vomit. After resting for a little time, he re-entered the retort for the third spell, which lasted for about ten minutes, and finished

the work. Thereafter, he felt somewhat shaky in the limbs, but this sensation passed off about half an hour later. Nevertheless he resumed his work on the following day and night, but was compelled to desist on the Saturday morning. He then felt weak and ill, and he observed that his urine had become very highly coloured. By advice of his medical attendant he remained off work for a week. The urine continued of this high colour for three days. Samples of the urine were forwarded to us for examination, but no blood-corpuscles or blood-colouring matter was found in them, although they bore a very high colour. Neither was any trace of arsenic detected in the combined samples, the total amount of which was eight ounces.

Since the foregoing fatal case was fully investigated, we have been informed by the medical officer of the work that the year previous he had attended another workman who, working at the same operation, had been seized with the like train of symptoms as E., and from which he died. The medical officer had not then realised the true nature or cause of the illness.

The Annual Reports of the Chief Inspector of Factories and Workshops for this country not infrequently contain cases. In the Report for the year 1902, the Medical Inspector indicates that twenty-seven cases with three deaths had come under his notice, viz. :—thirteen in the year 1899, and seven in 1900. These cases happened in three works, viz. :—(*a*) the manufacture of bleaching-powder (three cases with two deaths), (*b*) the manufacture of zinc chloride (thirteen cases with one death), and (*c*) in galvanising iron (seven cases without any fatal issue). The cases under (*a*) are those considered in this and the last chapter (Case XLI.), those under (*b*) in

Cases XXXI. and XXXIII., and those under (*c*) to be now considered.

1900. Case XLII.—An account of the seven cases which occurred in the galvanising work is found in the Annual Report for 1901, the circumstances being as follow:—The seven cases occurred at intervals within a period of two months, and the seven men who were attacked were "picklers," that is, men who are engaged in dipping the iron articles, which have later to be placed in the zinc bath, into dilute hydrochloric acid (1-3). They occurred in the Belston district. None of the other workmen engaged in any other part of the galvanising process was affected. All of the men suffered from headache, giddiness, weakness of limbs, and tremor. In some of the cases there were slight jaundice and hæmaturia in addition; and in a single case, acute dermatitis of hands and forearms. Analysis of the acid used showed 0·035 per cent of arsenic, a much less percentage than in the Ayrshire case (XLI.), which was 0·29 per cent, or in the Dixon Mann-Clegg cases (XXXI.), which was 0·309 per cent.

There were no cases reported for the years 1901 and 1903 in the Annual Reports for 1902 and 1904.

1903. Case XLIII.—Three men were engaged in soldering a pipe lying at the bottom of a tank which was four metres deep and three metres in diameter. The hydrogen flame was being used for the purpose. The gas was led by a rubber tube from the point of generation to the working-point. The men, after working for a time, stopped to take a meal. Resuming work thereafter, they began to perceive a bad smell in the tank and quickly were overcome by the gas. Fresh air was blown into the tank and the men rescued and brought round. One

however, died almost immediately, another next day, and the third on the following day. On examination, it was found that the rubber tube was old, and that a crack opening up permitted some of the gas to escape unburnt. The place of the leak was at a level with the faces of the workmen when the men were half kneeling at work. The acid was found on analysis to be strongly arsenical.[1]

1904. Case XLIV.—One case is reported in the Report of Inspector of Factories for 1905, the main facts of which are as follow:—The gas was evolved in the process of manufacturing zinc sulphate from crude sulphuric acid and zinc oxide. "The process was carried on in an uncovered vat in the open air, the sulphuric acid being conveyed there in an open trough. On the night in question, the man affected had attended as usual to the shovelling in of the zinc oxide—an operation taking only a few minutes—but remained about half an hour in the vicinity of the vat. He felt sick all night and collapsed at breakfast time. His symptoms were characteristic of this form of poisoning,—sudden onset of violent and excessive sickness and vomiting, collapse, hæmaturia for some days, rapid coppery jaundice, and subsequent anæmia." He recovered. The remedy employed to prevent recurrence of the danger was to remove the conduct of the process to a position where the fumes could be conveyed to the main chimney-stack.[2]

1905. Case XLV.—In the Report for 1906,[3] three cases are reported where the gas was generated in a process for the recovery of copper. These cases were under the charge of Dr. Mackenzie of Cheadle. The men attacked were employed in emptying vitriol solution

[1] *Chemische Industrie*, 1903, p. 317.
[2] P. 374. [3] P. 285.

from the depositing tanks. The symptoms were dizziness, collapse, followed by jaundice, hæmorrhage from the kidneys, and fever. "The tanks are supplied with sulphuric acid 70 grammes per litre and copper 35 grammes per litre. A current of electricity is passed through the fluid with lead anodes as the positive and copper cathodes as the negative poles. Oxygen and sulphurous acid gases are liberated from the positive pole, and copper deposited at the negative. No ill effects have been noted whilst these noxious fumes are given off. When the copper is all deposited, hydrogen is liberated at the negative pole, and I feel sure in combination with arsenic. The proof that arseniuretted hydrogen was given off in the process will be found in the report of Mr. Rogers."[1] Rogers reported that the copper sulphate solution contained arsenic compounds, for when the liquid was treated in the laboratory in exactly the same manner as in the factory, it was found to give off the arsenical gas in amounts sufficient to produce toxic effects. Since these cases arose, other harmless methods have been adopted to recover the copper.

Since going to press, Dr. Mackenzie has favoured us with the following further particulars of the three men attacked. 1. J. C., aged thirty, began to feel ill nine hours after working at the tanks. He felt cold, then shivered, and on micturition passed bloody urine. The doctor found him collapsed, slightly jaundiced, and complaining of severe cramps all over, abdominal pain, and frequency of micturition or desire to micturate. His urine on examination consisted of one-fourth blood. By the third day, the jaundice was intense. Patient was confined to bed for three weeks, and was six weeks away from work.

[1] P. 61.

2. J. E. W., aged twenty-three, felt quite well on leaving his work, but on his way home, two miles distant, a "heavy feeling" came over him. He could not take his usual meal, and what he did take he vomited; had severe pains in his loins and frequent desire to micturate. Jaundice of a severe type developed. His bowels were constipated. He was not able to return to work for thirteen weeks. 3. J. W., aged thirty-three, left his work in usual health, walked home a distance of one and a half miles, and ate a good supper. The urine which he passed after supper was bloody, this being the first indication of his being ill. He then vomited his food, and began to feel a "severe hammering" or throbbing in the head, which lasted three days. He frequently passed bloody urine, was severely jaundiced, and was constipated in his bowels. He had the sensation of "pins and needles" in his legs and feet, which continued for some time even after his return to work. He was off work for eight weeks.

Case XLVI.—Dr. Legge of the Home Office informs me that the following cases occurred in Finsbury, London, this year (1907). Two men were working at a process for the precipitation of gold from bismuth residuum at a bullion refinery. In the process about ten gallons of a solution of chloride of bismuth were being treated with zinc powder. The liquid was found later to contain nearly two per cent of arsenic chloride. The symptoms from which the men suffered were:—hæmoglobinuria, vomiting, anæmia, and great exhaustion. One case ended fatally.

Case XLVII.—For the information regarding the following case I am indebted to the same authority. In a chemical work in Widnes, a workman was engaged in cleaning out a tank in which commercial sulphuric acid was used. His employers were not satisfied with the acid

owing to the arsenic contained in it, and instructions were given for the tank to be thoroughly cleaned. The workman in fulfilling this duty used a galvanised iron pail to remove the sediment. The symptoms from which he suffered were:—vomiting, suppression of urine, melæna, then jaundice, and later, symptoms of thrombosis, and dyspnœa. He died.

CHAPTER XV.

ANALYTICAL METHODS FOR THE DETECTION OF ARSENIC IN SMALL AMOUNTS.

THE range of operation for the chemical detection of arsenic in the excretions of the persons or in the organs of the bodies of those who have been exposed to arseniuretted hydrogen is limited by the fact that the quantity of the gas necessary to produce grave effects or even fatal results is usually but small, and by the further fact that, by reason of the channel by which the gas gains entrance into the body, it is distributed more or less equally all over the system. It behoves, therefore, those whose duty it may be to examine either excretions or organs or portions of organs for the presence of arsenic to be prepared to do so, if it may be so expressed, micro-chemically. It becomes, in consequence, of the utmost importance that those who are charged with the duty of performing post-mortem examinations of the bodies of persons who are believed to have died from the effects of this gas, should preserve for the use of the analyst as much of the organs and fluids as is reasonably possible, in order that the highest accuracy in analytical results may be obtained.

It may be said at the outset that the amounts of arsenic which have to be dealt with in such cases do not lend themselves usually to ponderable methods, and that in many, if not, indeed, most cases, recourse must be had

to stain-methods or mirror-methods, which, by comparison with like stains or mirrors produced from known amounts of arsenious acid, may be translated into amounts by weight.

The tests or processes upon which chief reliance can be placed are these, viz. :—(1) Reinsch; (2) Marsh; and (3) Gutzeit, or its modifications. In addition, may be named the biological process, that of (4) Gosio or Abba.

1. *The Process of Reinsch.*—This was first described by Reinsch in 1843. The reagents required for this process are: (*a*) pure copper foil, and (*b*) pure hydrochloric acid. It is absolutely essential that in all tests for arsenic each reagent used must be proved to be arsenic-free. The purity of the copper may be tested in the following manner: To some pure hydrochloric acid add five equivalents in bulk of water and two or three drops of a weak solution of ferric chloride or ferric sulphate. After boiling the whole together for a few minutes, add one or two pieces of bright polished copper foil in the form of small strips while the mixture is boiling. If the metal is free from arsenic, its original bright polished appearance will remain unchanged, but if it contain arsenic, it will acquire a darkened or tarnished appearance.

To apply the test to the organs of the body, it is necessary to pound in a mortar to the consistency of pulp a fairly large portion of the organ, from which a weighed portion may be used for the test. To this weighed portion add in a suitable vessel distilled water containing one-sixth to one-eighth of its volume of pure hydrochloric acid, and heat to boiling, stirring the mixture during the time. Then add one small slip of the pure copper foil, about the size of one-quarter of an inch square, which is best attached to a piece of fine platinum wire of sufficient length to

permit of the foil being easily lifted out of the boiling vessel for observation during the currency of the experiment. If arsenic be present, the copper will become coated with a deposit, the colour and appearance of which will depend upon the amount of arsenic present. If the amount be small, the deposit may have the appearance of a slight greyish or faintly violet-bluish coloration only; if in larger amount, however, the deposit will likely be of a distinct grey colour. If necessary, additional slips of copper are added to the mixture until the deposit ceases to form. The stained copper slips are now to be carefully washed in distilled water, in alcohol, and in ether in turn, and are then carefully dried between pieces of clean absorbent paper. They are next cut up into small pieces and placed in a clean sublimation tube, which is gently and gradually heated over a flame, when the deposit on the copper will sublime and be deposited on a cool part of the tube. This sublimate when examined with a magnifying lens will, if composed of arsenious oxide, be found to consist of minute crystals octahedral or tetrahedral in form, but mainly of the former shape. The part of the tube containing the sublimate may now be cut off and placed in a clean test-tube, to which is added water faintly acidulated with pure hydrochloric acid, the whole being shaken together during the process of heating it to boiling, so as to ensure complete solution of the crystals. Through the fluid in the test-tube ought now to be passed a fine current of washed sulphuretted hydrogen gas (H_2S), when a lemon-yellow precipitate, probably only easily distinguishable in the case of minute amounts of arsenic by looking down through the contents of the tube against a white ground, will be seen to have formed. This precipitate is insoluble in water, ether, alcohol, hydrochloric acid, and vegetable acids, but is

soluble in potassium, sodium, and ammonium hydrates, by which, and by further corroboratory tests, the presence of arsenic is proved. The deposit which forms on the copper from arsenic seems to be of the nature of an alloy having the composition of Cu_5As_2. Very minute amounts of arsenic in the form of arsenious oxide are sufficient to form a distinct deposit: indeed, one-hundredth of a grain ($\frac{1}{100}$th) is sufficient to give a well-marked iron-grey deposit, and even smaller fractions of a grain, a steel-grey deposit. In order to prove that the yellow precipitate formed by H_2S is arsenious sulphide, the above is all that is needed, after its insolubility in the reagents named has been proved. But it ought to be kept in mind that other substances besides arsenic give yellow-coloured precipitates with that reagent, *e.g.*, cadmium, selenium, stannic compounds, and antimony. The sulphide of cadmium, however, is soluble in hydrochloric acid and is insoluble in alkalies, that of selenium changes in colour from yellow to reddish-yellow or even orange-red, and is insoluble in ammonium hydrate, while that of antimony, which is orange-red in colour, is soluble in strong hydrochloric acid and practically insoluble in ammonium hydrate. The likelihood that tin is present is ruled out of count by the fact that the stained copper does not yield a crystalline sublimate on being heated in a reduction tube. Careful consideration must be given, when small amounts of arsenic are being looked for, to the possibility of minute amounts of selenious acid or its salts being also present. Rosenheim (*op. cit.*) has shown, as Reinsch himself was aware,[1] that selenious acid forms a black deposit on copper foil, and that when sublimed in a sublimation tube it formed a crystalline sublimate. But this sublimate is composed of

[1] *Neues Jahrbuch f. Pharm.* 1866, 203.

prismatic crystals which are very hygroscopic. Rosenheim proposes to determine the presence or absence of selenium by substituting at first silver foil for the copper foil. If it be present, it will be deposited on the silver foil as a blackish deposit. Thereafter the copper foil may be added, upon which the arsenic will be deposited, if present.

The most reliable characteristic of the presence of arsenic in Reinsch's process may be held to be the formation of octahedral crystals in the sublimate. In order to carry out the process efficiently, small slips of copper ought only to be used, and the mixture ought to be boiled for at least half an hour, fresh water being added to supply that lost by evaporation. Arsenic, however, is not the only substance which may be deposited on the copper in this process, for antimony, mercury, bismuth, selenium, and silver form like deposits. But the volatility of the deposit on heating the sublimation tube, its sublimation on a cool part of the tube, and the definite crystalline form of the sublimate serve to differentiate arsenic from other substances, since the sublimate of mercury consists of fine globules of that metal, and that of antimony is either amorphous or granular in character.

It is of equal importance that the hydrochloric acid as well as the copper should be perfectly arsenic-free. But unfortunately it is very difficult, if not impossible, to purchase ordinary acid which is free from that impurity. Various means have been proposed to secure pure acid.

The Joint Committee of the Society of Chemical Industry and of Public Analysts recommended in their report[1] the following method:—Dilute the purest acid of

[1] *Analyst*, 1902, xxvii. 48; Arsenical Commission, 1903, Evidence, vol. ii. Appendix 20.

commerce with distilled water to a sp. gr. of 1·10, add sufficient bromine to colour the mixture of a strong yellow colour (about 5 c.c. per litre will suffice), then add *in excess* sulphurous acid either in the gaseous or liquid form. Allow the mixture to stand for twelve to eighteen hours. Thereafter boil mixture till about one-fifth of the bulk has evaporated. The residue may then be used directly or may be distilled if thought necessary, but the arsenic will have been volatilised in the form of chloride in the part boiled off.

Thorpe and Jeffers[1] have recommended a modification of Reinsch's process to effect the same end, which is carried out as follows:—The acid to be treated is diluted until its sp. gr. is about 1·10, is then raised to boiling point, and at this stage a piece of copper gauze of fine mesh, after being ignited gently, is introduced. The gauze recommended should have 100 meshes to the inch, and should be of the purest copper. For each litre of acid under treatment a piece of gauze of two inches square should be added, and be rolled loosely round a glass rod flattened at its lower end for the purpose of easier introduction into and removal from the acid. During the process of boiling, the arsenic, if present, becomes deposited on the copper gauze. At the end of one hour, the first piece, if stained, should be removed and a fresh piece introduced, the boiling being the while continued. So long as a fresh piece becomes stained, a new piece must be added until the last added piece remains perfectly bright. According to the observers quoted, ordinary good acid will require two or three pieces before the acid is freed from its contained arsenic. When this point has been attained, the acid is transferred to a clean retort, a fresh piece of gauze is introduced, and

[1] *Journ. Chem. Soc.* P. vol. xviii. 252, 118.

distillation is commenced. The first part of the distillate should be rejected, and it is best not to continue the process to a point too near the end of the contents. The distillate consists of constant boiling-point acid. They also recommend that the acid, after digesting at boiling point, should not be allowed to cool in contact with the air before being

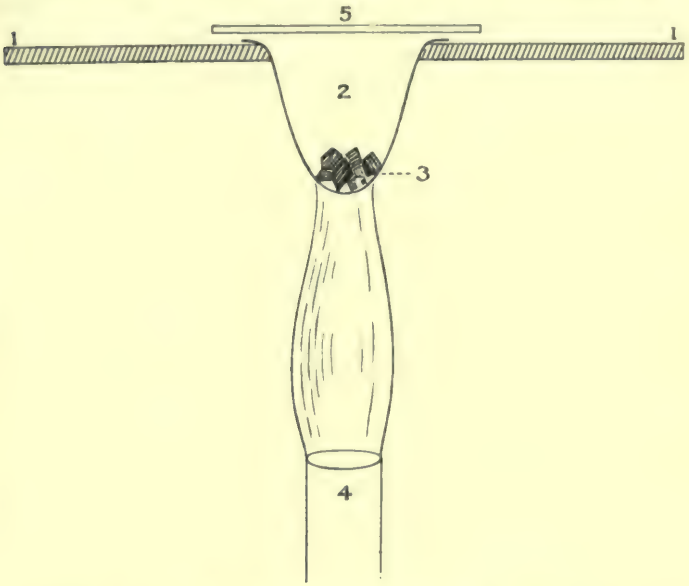

FIG. 2.—Délepine's Apparatus.

1, iron plate; 2, copper cone; 3, pieces of copper foil with deposit in Reinsch's process; 4, small Bunsen burner; 5, cover-glass on top of cone.

put in the retort, else the copper is liable to be attacked by the acid.

Sheridan Délepine[1] has suggested another method resembling one suggested by a Committee of the National Health Society,[2] and has given a description of a workable

[1] *Brit. Med. Journ.* vol. i., 1901, p. 81. [2] *Ibid.* vol. i., 1883, p. 1220.

apparatus for the detection of the sublimate obtained from the copper foil used in the process of Reinsch. He gives a sketch of the apparatus, which we reproduce with his permission, Fig. 2. The size of the pieces of pure copper foil which he has found most serviceable is one-quarter of an inch square. These are immersed in the boiling fluid suspected to contain arsenic for three-quarters of an hour to one hour. Thereafter the copper slips, carefully dried, are introduced, after clipping into smaller pieces, into a small cone of pure copper foil, the exact measurements of which are five-eighths of an inch in diameter and half an inch in height. The open end of the cone has a lipped rim which rests upon the circular edge of a hole in an iron plate, which is one-eighth of an inch in thickness and four inches in diameter, the perforation in the plate measuring five-eighths of an inch in diameter. On the mouth of the copper cone is placed a cover-glass measuring seven-eighths of an inch in diameter. After a blank experiment has been made with the cone and cover-glass by heating the former, in order to prove the purity of the copper, and after the cone has been allowed to cool, the copper slips from the suspected material are placed in the apex of the cone, and heat is applied gently thereto from a small Bunsen burner. Sublimation should then take place, if arsenic be present, and the sublimate should form on the under surface of the cover-glass. The cover-glass, or a series of these if the sublimate be relatively large in amount, should then be examined by the microscope, magnifying 600 diameters or upwards, to distinguish the characteristic crystalline form of arsenious oxide. In this way, by using successive cover-glasses, the whole of the arsenic may be sublimed. By using sublimates from definite known amounts of arsenious acid for comparison, it is possible to devise a fairly accurate

method of quantitative analysis. It is possible by Reinsch's process to obtain small but definite crystals of arsenious oxide from a fluid to which 0·00005 gramme, or 0·005 mgrm. As_2O_3 has been added.

2. *Marsh's Process*, or *Marsh-Berzelius Process.*—The name associated with the process originally is that of Marsh of Woolwich, who in 1836 was the first to employ the use of nascent hydrogen in the detection of arsenic. The process depends on the fact that soluble arsenical

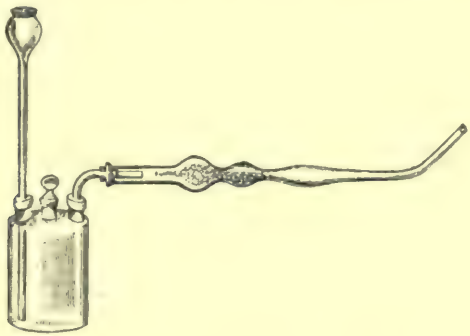

FIG. 3.—Marsh's Apparatus. A simple form.

compounds are decomposed in the presence of nascent hydrogen to form arseniuretted hydrogen. In the original process, Marsh generated the hydrogen from zinc and sulphuric acid, and in the use of the process since his time, hydrochloric acid has been employed by some instead of the sulphuric acid. Fig. 3. By reason, however, of the risks of unreliable results from the use of impure reagents, several modifications of the process respecting the generation of the hydrogen have been suggested. For example, Roussin has urged the use of magnesium instead of zinc because of the difficulty of procuring the latter metal in an

arsenic-free state. Others have suggested the use of sodium amalgam, which may be made arsenic-free in the following way :—melt one part of pure metallic sodium under paraffin wax, and gradually add, with constant stirring, ten parts of purified mercury, by which an amalgam or alloy is produced, which, when the melted paraffin is decanted off and the mass is washed with pure benzine, is ready for use. A few small pieces of the alloy are sufficient

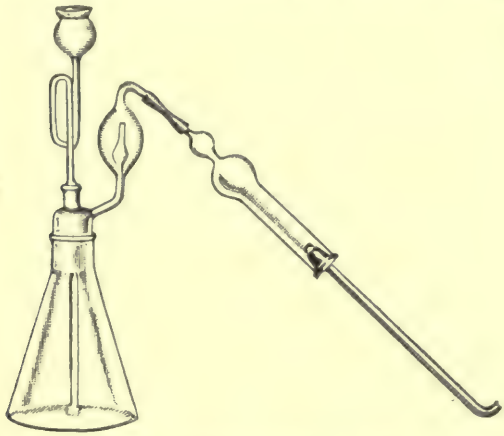

Fig. 4.—Tyrer's Apparatus for Marsh's Zinc-Acid Process.

for one estimation. When zinc is employed, care has to be taken that it does not contain any marked traces of iron, as this metal inhibits the evolution of the arsenical gas. Some chemists, however, as Allen, hold it to be essential for the even evolution of hydrogen and for the formation of uniformly deposited mirrors, that the zinc used should contain a trace of iron. Whether this latter view be correct, however, is subject to divergence of opinion, although most, if not all, chemists are quite agreed that

marked traces of iron do exercise this inhibitory effect to the extent of preventing some portion of arsenic present in the material under examination from being liberated in the form of arseniuretted hydrogen. Fig. 4. Notwithstanding these difficulties, many chemists prefer the Marsh-Berzelius method for the purpose of detecting minute amounts of arsenic in materials: but it is quite clear that if the reagents used are pure, those originally proposed and employed by Marsh will efficiently serve the purpose. To get rid of any risks of impurity, and of any doubt that any arsenic which may be present has not been given up because of the presence of iron in the zinc, Bloxam[1] suggested the method of generating the hydrogen from the electrolytic decomposition of water. This method has been recommended by the Inland Revenue Departmental Committee,[2] in whose report details of carrying out the process are given, which we shall quote later.

It may be said, therefore, that two main methods are in vogue connected with the Marsh-Berzelius method, viz.:—(*a*) The zinc-acid method, and (*b*) the electrolytic method. These deserve some detailed consideration.

1. *The Zinc-Acid Method.*—The method proposed by the Joint Committee of Analysts is as follows:—

Materials Required. — These are hydrochloric acid sulphuric acid, nitric acid, zinc, caustic lime or magnesia, and calcium chloride. These materials must be arsenic-free, and their purity must be assured before tests are carried out. The mode of obtaining pure hydrochloric acid has already been described. To purify sulphuric acid, add to about half a litre of the purest commercial acid a few grammes of pure sodium chloride, distil

[1] *Quart. Journ. Chem. Soc.* vol. xiii. pp. 12 and 338.
[2] *Arsenical Commission*, vol. ii. App. 21, p. 208.

from a non-tubulated glass retort, rejecting the first 50 c.c. of distillate, and for use in the test employ one part of purified acid product with four parts of water. Nitric acid is obtainable in an arsenic-free condition, but to prove its purity, it is best to evaporate 20 c.c. of the acid in a porcelain dish to dryness, and thereafter wash the residue out with dilute acid and test in the Marsh-Berzelius apparatus hereafter described. It is recommended that all acids should be purified as required, and not used after being stored for any length of time. If and when stored, however, they should be kept in Jena glass flasks, because most ordinary bottle glass contains, and may communicate to the acid contained therein, traces of arsenic. Arsenic-free zinc prepared electrolytically is now purchasable. When bought in block, it should be re-melted in a crucible and granulated by pouring it in drops into cold water from a height of three or four feet. It should be carefully examined for iron, and if substantial traces happen to be present, it should be rejected. Calcium chloride being used in the drying-tube of the apparatus through which the arsenical gas has to pass, it like other substances must be pure. To purify it, ordinary calcium chloride should be moistened with strong pure hydrochloric acid, then fused by heat, and re-granulated in the usual way.

Apparatus.—This consists of (*a*) a flask of about 200 c.c. capacity, which is fitted with (*b*) a doubly-bored cork, or, preferably, a ground-glass connection, carrying (*c*) a tapped glass funnel of about 50 c.c. capacity, and (*d*) an exit tube. Connected with the exit tube is (*e*) a drying-tube which contains the following drying material placed in the following order, (1) a roll of blotting-paper or filter-paper soaked in lead acetate

solution and dried, (2) a wad of cotton wool, (3) a layer of granulated calcium chloride composed of granules about the size of small shot, and, last of all, (4) a thick wad of cotton-wool. To the end of the drying-tube is fitted (*g*) a hard glass tube drawn out, and of such a diameter that at the place where the mirror of arsenic is to be expected the tube will just pass through a No. 13 Birmingham wire-gauge, equalling in size 0·092 of an inch. It is of especial importance, when comparisons have to be made with standard mirrors, that these tubes should be of exactly

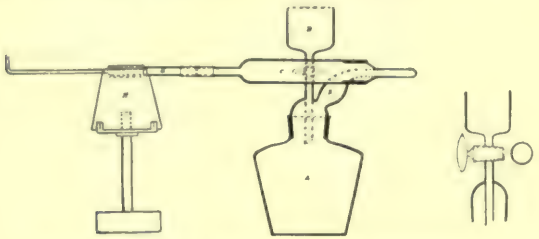

FIG. 5.—Zinc-Acid Marsh Apparatus, diagrammatic.

Order of parts may be followed from the text:—*a*, hydrogen flask; *b*, glass stopper connection, exit tube, and tap-funnel; *c*, drying-tube; *g*, hard glass tube; *h*, Bunsen burner.

similar sizes, or as near as may be, for accuracy of conclusions to be made. Wrapped round the portion of the tube to be heated is a piece of moderately fine copper gauze, about one inch square, to ensure equal distribution of the heat and the uniform distribution of the deposit or mirror. A Bunsen burner (*h*) used to heat the hard glass tube close to the constriction completes the apparatus. The tube should be heated to the extent of one inch, including the shoulder.

Modus Operandi.—Wash about 20 grammes of the zinc with distilled water and place them in the flask.

Connect the various parts above described. Put into the funnel a sufficient amount of the acid, prepared as described, and allow it to flow into the flask, whereupon a brisk evolution of hydrogen will ensue. After air has been expelled from the entire apparatus by the hydrogen, light the hydrogen jet. When the jet burns with a rounded tip, it may be taken as certain that all air has been expelled. Now place the Bunsen burner under the

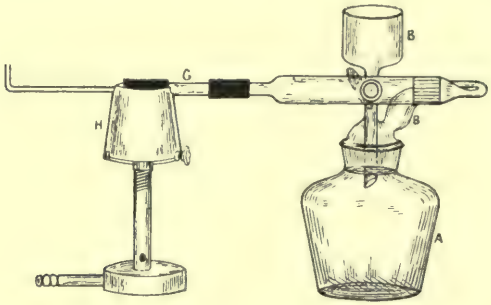

FIG. 6.—Marsh's Zinc-Acid Apparatus, improved form.

A, flask ; *B*, ground-glass stopper connection and tap-funnel ; *D*, exit tube, containing absorbents ; *G*, hard glass tube ; *H*, Bunsen burner.

hard glass tube at the place described, and run in more acid as needed. After half an hour's heating, and if no mirror be deposited inside the tube, then it may be held as certain that neither acid nor zinc contains any arsenic. In adding the acid the entrance of bubbles of air should be prevented, as the entrance of air tends to make any deposit, if it form, blackish in colour. It is best, therefore, to keep the funnel partly full of the dilute acid. Assuming that there is no formation of mirror, then the materials are proved to be arsenic-free. Should any mirror be present, it proves that one or other or both of the reagents

contain arsenic. This may be ascertained by further examination of the materials taken separately.

When the materials have been proved to be devoid of arsenic, a series of standard mirrors may now be made. For this purpose a solution of arsenious oxide in hydrochloric acid is made, one c.c. of which contains 0·001 milligramme As_2O_3 or As_4O_6. This is made from a stronger solution, as is afterwards described. Mirrors are made with different amounts of this solution. For example, two c.c. will give the mirror resulting from 0·002 of arsenious oxide, four c.c. of 0·004, and so on. It is best to prepare, at least, mirrors from not only the foregoing amounts, but also of 0·006, 0·008, and 0·01 of As_4O_6. These, after having been sealed at the ends, should be mounted on white cards and be properly marked for reference and comparison. Some operators are of opinion that hydrochloric acid gives better defined mirrors than sulphuric acid; but whatever the acid used in the formation of the standard mirrors, the same must be employed in testing materials as to their arsenical content. One advantage of the former acid over the latter is that it may be employed without previous destruction of the organic matter.

2. *The Electrolytic Method.*—This method, founded on the proposal of Bloxam, has been reported on by the Inland Revenue Departmental Committee,[1] and is said to give trustworthy results, provided that the details as set forth by the Committee are strictly observed. It is especially claimed for this process that it gives more definite mirrors than the zinc-acid method when the electric current is properly managed and other precautions are taken. It is now employed in the Government

[1] *Arsenical Commission*, vol. ii. App. 21, p. 208.

laboratories.[1] It involves, when properly arranged in detail, comparatively little time and trouble. The apparatus consists of the following parts:—Fig. 7. (1) A glass vessel *A*, provided with a ground-glass stopper and the connections which consist of exit tube and funnel, *B*, and a calcium chloride tube, *C*; (2) a porous cell, *D*; (3) a glass vessel, *E*; (4) a cooling vessel, *F*; (5) a hard glass constricted tube, *G*; and (6) a small Bunsen burner, *H*.

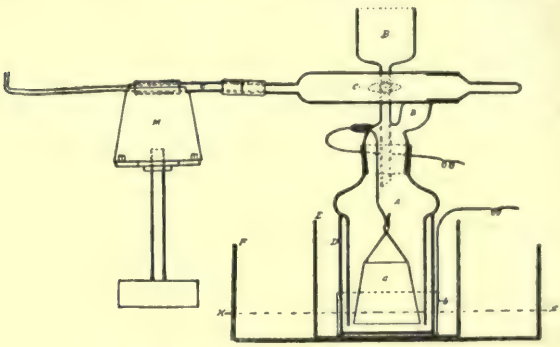

FIG. 7.—Electrolysis Apparatus.

Parts are described in text:—*A*, glass vessel; *B*, glass stopper connection, exit tube, and tap-funnel; *C*, drying tube; *D*, porous cell; *E*, glass cell; *F*, glass vessel for cold water; *G*, hard glass tube; *H*, Bunsen burner. *a*, cathode; *b*, anode.

We now quote the descriptive sketch of details of the apparatus[2]:—"The glass vessel *A* forms with the porous vessel *D* the inner cell for the cathode where the hydrogen and arseniuretted hydrogen are produced on passing the electric current. The vessel *A* is open at the bottom and fitted at the top with the ground-glass stopper *B*, through which is passed to a point just below the neck of the vessel the stem of the tapped funnel. The glass stopper also carries the gas exit tube on which is a bulb.

[1] Thorpe, *Trans. Chem. Soc.* 1903, vol. 83, pp. 974-986.
[2] *Arsenical Commission*, vol. ii. App. 21, p. 208.

The tube is bent as shown in the drawing, and is connected by grinding with the drying tube *C*. Through the glass cap is fused a stout platinum wire for making the connection on the outside with the current, and within the vessel with the electrode. The inner electrode, forming the cathode, is of sheet platinum and cone-shaped, with several perforations. It is suspended from a hook made on the end of the wire passing through the

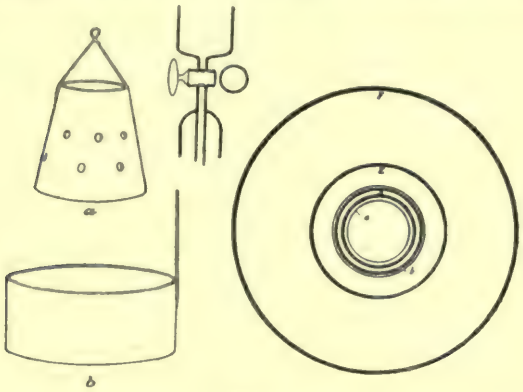

FIG. 8.

a, cathode; *b*, anode. Figure also shows glass stopper of tap-funnel, and section plan of glass parts and porous cell. Circular figure represents horizontal section at *x*, *x*, in Fig. 7.

glass stopper, and is adjusted so that when the stopper is inserted in the vessel the lower edge of the electrode is 1 mm. above the bottom of the vessel *A*. It is then securely attached to the wire by closing the hook. The porous vessel *D* is larger by 2 to 3 mm. in diameter and in depth than the cylindrical portion of the glass vessel *A*. As seen in the figure, *A* rests by means of its bulged-out shoulder upon the upper edge of *D*. The porous vessel is of unglazed highly silicious ware—of the com-

position employed for the well-known biscuit filters, first made by Dr. Pukal—and is from 1 to 1·5 mm. in thickness. The cell for the anode consists of the stout vessel *E* upon the flat bottom of which the porous vessel *D*, containing the glass vessel *A*, stands. The anode consists of a band of platinum 2 cm. broad, passing loosely round the porous cell, and connected with the current by means of a stout platinum wire. The liquid in the vessel *E* should be kept below 50° C., and the vessel *E* is therefore placed in the larger dish *F* containing cold water.

"The drying tube *C* is packed as follows:—A plug of cotton wool is first inserted, and then pure granulated anhydrous calcium chloride, in pieces about the size of small shot or malt grains, for a length of 5 cm. Another loose plug of cotton wool is placed upon the calcium chloride, followed by a roll of lead acetate paper. This is prepared by soaking filter paper in a cold saturated solution of lead acetate and then drying the paper in air. The paper is cut into strips about 1 cm. broad, and rolled into a coil fitting loosely in the tube. A small spiral coil of lead acetate paper is also placed within the enlarged end of the exit tube to which the calcium chloride tube is attached. To the other end of the drying tube there is fixed by means of a short piece of unvulcanised rubber tubing the hard glass constricted tube in which the arsenic is to be deposited. The ends of the drying tube and the hard glass tube should be in close contact beneath the rubber. To make one of these tubes a piece of Jena glass tubing having an external diameter of 5 mm. and an internal diameter of 3·5 mm. is cleaned by successive treatment with acid, water, and alcohol, and dried. It is then held in the blow-pipe flame, so that a portion of the tube about 2 cm. in length and 5 cm. from

the end of the tube is thoroughly softened, when the heated portion is drawn out to a length of 7 to 8 cm., and having at a distance of 1 cm. from the shoulder of the tube an external diameter of 2 mm., a size which should be maintained as nearly as possible throughout the length of the constricted part. The tube is cut off near the end of the drawn-out portion, the last 1 cm. of which is turned up at right angles. The hard glass tube is supported in a horizontal position when attached to the drying tube of the apparatus, by resting in the slots on the upper edge of the cone which surrounds the flame of

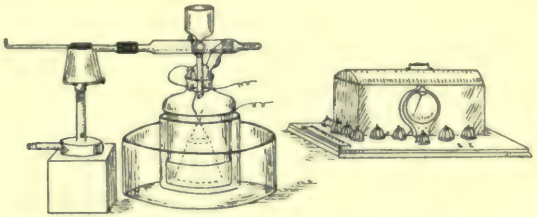

FIG. 9.—Electrolysis Apparatus in working position, with rheostat.

the small Bunsen burner. A piece of platinum gauze about 2 cm. square is wrapped round the hard glass tube at the point where it is to be heated by the Bunsen flame.

"The small Bunsen burner has a circular base 12 mm. high, and its tube is 6 cm. in height and 5 mm. in internal diameter. The upper portion of the tube is threaded and carries a gallery upon which rests a copper cone. The upper edge of the cone contains two slots to receive the hard glass tube. The apparatus, when worked in the manner to be described, has an apparent resistance of 1·4 ohms, the potential difference between the ends of the wires of the poles being 7 volts with a current of 5

ampères. This strength of current gives about 40 cubic centimetres of hydrogen in a minute, which furnishes a steady flame about 2 mm. in height, and is the strength of current recommended to be used for the purposes of the test. To effect the reduction of the intensity of the main

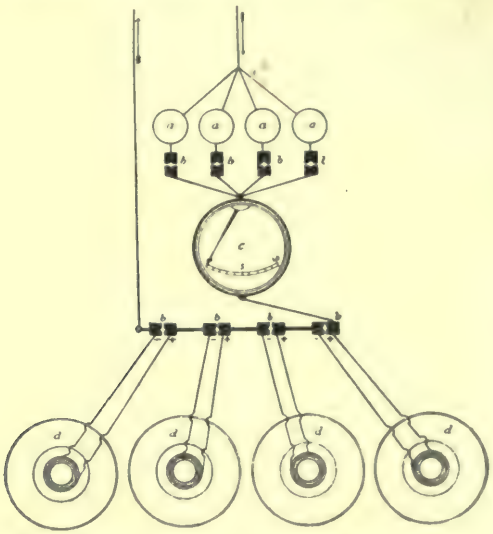

FIG. 10.—Diagrammatic plan of incandescent lamps, rheostat, and four apparatus in series.

a, *a*, *a*, *a*, lamps; *b*, *b*, *b*, *b*, switches; *c*, ammeter; *d*, *d*, *d*, *d*, electrolytic cells, as in Figs. 7 and 8. Arrows indicate direction of electric current.

laboratory supply, which is the most convenient source of the current, a rheostat of incandescent lamps may be employed. The lamps are arranged in parallel with each other, but in series with the apparatus, and, according to the current desired, lamps of different candle power may be inserted. An ampère meter or ammeter is included in the circuit. The apparatus may be arranged for the

simultaneous execution of a number of tests. By suitable construction on the charging board, the electric current passes through the solutions arranged in series, and any of these may be brought into or cut out of the circuit as desired. The current is brought to the required strength —4·5 to 5 ampères—by the introduction in the rheostat of lamps of the requisite power according to the number of tests to be carried out simultaneously."

The sulphuric acid employed consists of a mixture of one volume of pure concentrated acid with seven volumes of water. It must, of course, be arsenic-free, and be proved to be so before use.

Modus Operandi.—The apparatus is arranged for the test, as described, and the test carried out as follows:— "The cells, electrodes, and glass vessel *A* with the cap, funnel, and exit tube, are thoroughly cleaned and rinsed with distilled water. The porous vessel *D* containing the vessel *A* is placed in *E*, which is surrounded by cold water contained in the glass dish *F*. The calcium chloride tube *C*, which has been packed in the manner described, is fitted on the ground-glass connection. The hard glass tube *G* is attached to the drying tube by the rubber connection, so that the bent portion at the end is in an upright position, and the platinum gauze is so arranged on the tube that it just overhangs the shoulder. The small Bunsen burner *H* is placed beneath the tube which rests in the slots on the upper edge of the cone in such a position that, when lighted, the flame will heat about 2 cm. of the tube just before the constriction commences. The connections with the battery wires are made by means of binding screws in such a manner that the current will pass from the vessel *E* to the cell *D*; 30 c.c. of the dilute sulphuric acid are then poured into *E*, containing the

anode, and 20 c.c. of dilute acid are also run into the cell *D* by means of the stoppered funnel *B*, the stem of which must be left full of liquid.

"When all the connections are complete, and the acid has been added, the current is switched on and the time noted. At the end of 10 minutes the apparatus is practically free from air, and the issuing hydrogen may be lighted. At the same time the Bunsen burner is lighted, and the flame carefully adjusted so that the small piece of platinum gauze is maintained at a red heat throughout the experiment. The heating of the tube during the passing of the gas is continued for 15 minutes, and if during that time no brown ring or deposit of arsenic has been formed in the constricted tube (best seen by holding a white card beneath the tube) the apparatus and the acid used may be considered free from arsenic and suitable for the application of the test. Two c.c. of amyl alcohol are then run into the inner cell *D* by means of the tapped funnel *B*. This is at once followed by the addition of the solution to be tested, prepared as described, 5 c.c. of water being used for rinsing out the containing vessel. No air must be admitted, and the stem of the funnel must be left full of liquid. If arsenic is present in the added liquid, a deposit begins to form in the narrow tube, in the course of a few minutes, at a point between 1 cm. and 2 cm. from the heated shoulder. At the end of 30 minutes, the whole of the arsenic, except in extreme cases, will have deposited in the tube, which is now sealed up while full of hydrogen. This is effected in the following manner. The stopper of the funnel is opened, and a small pointed flame is at once directed against the narrow tube at a point 3 cm. from the deposit, between the deposit and the turned-up end of the tube, which is meanwhile held by a

pair of forceps. The tube at once collapses, and the end is drawn off. The electric current is at the same time disconnected, and then the tube is similarly heated and drawn off just below the shoulder. The deposit of arsenic must on no account be heated by the flame during the sealing of the tube. The short tube, about 4 cm. long, containing the arsenic deposit, may then be mounted on a white card for reference. Of course, if the deposit thus obtained should be so considerable as to prevent accurate comparison with the standard deposits, the experiment must be repeated upon a smaller quantity of the substance.

"*Preparation of the Standard Deposits.*—Although there is good reason to believe that the amount of arsenic deposited is in nowise affected by the nature of the substance with which the arsenic may be associated—0·01 mgrm. of arsenic in beer, for example, giving a deposit of equal intensity with the same quantity of arsenic in malt —nevertheless, as the quantitative estimation is based on comparison, it is expedient to make use of deposits prepared by the addition of known amounts of arsenic to arsenic-free specimens of each class of substance. By so proceeding, all doubts which may arise from differences in manipulation, or concerning the possible effect of differences in the nature and composition of the substances on the formation of the deposit are obviated. The preparation of a solution of arsenic of definite strength for this purpose must be carefully carried out. Pure, re-sublimed arsenious oxide is ground to a fine powder in an agate mortar, and dried at 100° C. 0·1 gramme is accurately weighed on a watch glass, and transferred to a litre flask by washing it down a funnel placed in the neck of the flask with one or two c.c. of pure concentrated hydrochloric acid. The liquid must not be heated. When the solution is complete,

it is diluted to one litre with distilled water, and thoroughly mixed. Each cubic centimetre of this solution (conveniently called *A*) contains 0·0001 gramme, or 0·1 mgrm. of arsenious oxide. Of this solution 100 c.c. are carefully measured and transferred to another litre flask, and diluted with water to one litre. This solution (conveniently called *B*) contains in each c.c. 0·00001 gramme, or 0·01 mgrm. of arsenious oxide." After every small number of estimations the contents of the drying tube must be replaced by pure fresh materials.

Advantages of the Electrolytic Method.—These may be summed up as follows:—(*a*), it obviates the use of zinc; (*b*), it is easy to execute, is under perfect control, and can be carried out under such parallel conditions that strictly comparable results may be obtained; (*c*), the whole or an aliquot portion of the fluid suspected to contain arsenic may be put in the apparatus at once, so that the fluid is under the influence of nascent hydrogen all the time; (*d*), the deposits obtained are more uniform in character than those got from the acid-zinc method, since the quality of the zinc determines in some measure the amount of arsenic liberated, and the deposits by the above method can, therefore, be estimated quantitatively with greater accuracy; and (*e*), several tests may simultaneously be carried out. Of course, the initial cost of installation is greater than in the acid-zinc method, but that is of little importance when accuracy is the desideratum; and besides, it is only available if an electric current of sufficient intensity is at hand.

Another method employed by some chemists, notably Scudder,[1] and with modifications by M'Gowan and Finlow,[2]

[1] *Arsenical Commission*, vol. i. Q. 4270 *et seq.*
[2] *Op. cit.* vol. ii. App. 22.

is that in which the hydrogen is generated in a Kipp apparatus. Fig. 11. The hydrogen produced in the Kipp apparatus is first passed through a gas tower filled with beads moistened with mercuric chloride solution, and then through two towers with beads moistened with a solution of silver nitrate, in order to rid the hydrogen of impurities. In the M'Gowan-Finlow apparatus, the Kipp supply of hydrogen before reaching the Marsh flask is purified in

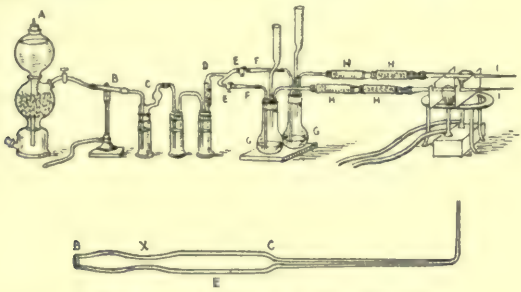

FIG. 11.—M'Gowan-Finlow Apparatus.

A, Kipp H-generating apparatus; *B*, Jena glass tube, kept red-hot; *C*, wash-bottle, containing strong H_2SO_4; *D*, *D*, wash-bottles containing solution of $AgNO_3$; *E*, *E*, screw-clips; *F*, *F*, capillary glass tubes; *G*, *G*, generating flasks, with funnels attached; *H*, *H*, *H*, *H*, absorbent and drying tubes; *I*, *I*, mirror tubes.
Lower figure represents enlarged view of Mirror Tube. *B*, fits with drying tube; *X*, point of fusion when mirror is deposited; *E*, point at which tube is heated to redness; *C*, shoulder of tube. Arsenical mirror is deposited between *C* and upturned point of tube.

the following manner, viz.:—it is passed in succession through (1), a tube (*B*) of Jena glass about 4 mm. to 6 mm. internal diameter made red-hot and kept in that state with a good Bunsen burner, (2), through a small narrow glass-stoppered wash-bottle of about 30 c.c. capacity containing strong sulphuric acid, *C*, to absorb heavy hydrocarbons, then (3), through two similar wash-bottles, *D*, *D*, each of about 40 c.c. capacity, containing strong solution of silver nitrate, the second of these having attached to it a small glass tower filled with small broken glass moistened

with the same solution—for the purpose of absorbing any traces of arsenic or sulphuretted hydrogen which may have escaped the red-hot tube *B*. Between the last wash-bottle and the Marsh or generating flask is placed a short, rather wide, capillary glass tube *F*, which is joined to the tower on the last wash-bottle by a short piece of pressure rubber tubing which is governed by a screw-clip, in order to regulate the flow of hydrogen from the Kipp apparatus. This capillary tube is united by tubing with the Marsh generating flask *G*, to which are attached short tubes *H*, *H*, containing respectively (1), filter-paper moistened with acetate of lead solution and dried, and (2), small pieces of fused calcium chloride, to the end of which is added the mirror tube, *I*. The Marsh or generating flask is made from tubing the bore of which before being blown just fits a No. 6 rubber stopper. The bulb of the flask has a capacity of about 70 c.c., the neck being approximately 9 cm. in length. Into the mouth of the flask is fitted a three-holed rubber stopper, through one hole of which passes the tube which brings the hydrogen from the Kipp apparatus, and which passes below the level of the liquid in the flask, through the second passes a long, narrow tap funnel with glass stopcock, capable of holding about 10 c.c. of liquid, and which is used for admitting into the flask either the acid or the liquid to be tested, and through the third passes the tube in which is placed the lead acetate paper. The substances placed in these tubes are for the purpose of absorbing any sulphuretted hydrogen and watery vapour which may be liberated from the Marsh or generating flask. The mirror tube, *I*, is made from thick-walled, milky Jena glass tubing of about 5 mm. external diameter. A length of this tubing is thickened in the flame and drawn out

in the blow-pipe flame until the internal diameter of the part out-drawn is about 1 mm., its length being about 9 to 10 cm. The fine end of the tube is up-turned and its aperture made very minute, in order to prevent back-draught or backward diffusion of air into the tube. Its wide end, which is about 12 cm. from the shoulder *C*, is constricted somewhat to permit of connection with the rubber tubing which connects it and the calcium chloride tube together, and about the middle of this wide part another constriction is made to permit of easier fusion of the tube at this point at the completion of an estimation. The mirror tube is supported at two points on an ordinary round tripod, two screens of tinned iron being the actual resting points, these also serving to protect the Bunsen burner from draughts. It is also well to support by means of a wooden clamp the fine end of the mirror tube, to prevent it bending or buckling during the time of heating.

Modus Operandi.—The part of the apparatus connected with the purification of the hydrogen from the Kipp apparatus is first duly fitted in the manner already described, and the current of hydrogen is turned on. Then 3 grammes of zinc and about 30 c.c. of water are introduced into the generating or Marsh flask. The whole apparatus is now completely connected, excepting the mirror tube, and the hydrogen from the Kipp allowed to flow through it for about ten minutes at the rate of about four bubbles per second. The mirror tube is now attached, and the flow of hydrogen passed through it for another additional five minutes, after which the Bunsen burner under the mirror tube is lighted. If at the end of ten minutes' heating no deposit forms in the mirror tube, the flow of hydrogen is reduced to the rate of about

one bubble per second, the diluted acid (10 c.c. of 1 in 4 sulphuric acid, or 10 c.c. of hydrochloric acid of 1·10 sp. gr.) is run into the generating flask, and heating is again applied for ten minutes to the mirror tube. If no deposit occurs in the tube at the end of that time, the reagents can be considered arsenic-free. At this stage, the material to be tested, in liquid form, is run into the flask by means of the funnel, and the process is continued for at least

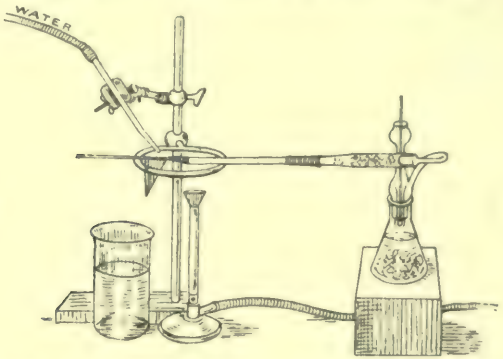

FIG. 12.—Thomson's Modification of Marsh's Apparatus.

The chief difference is that the mirror tube, distal to the Bunsen flame, is kept cool by water which trickles upon a conically-folded piece of filter-paper.

one hour longer, at the end of which time the whole of the arsenic, if present, will be deposited as a mirror in the tube. At this stage, the flow of hydrogen from the Kipp is increased in rapidity for a few minutes, the mirror tube is fused off at the point *X*, and then at the point *E* (Fig. 11), is then labelled, mounted on a card, and compared with the standard mirrors already prepared under exactly parallel conditions. It is advisable that the volume of liquid, 50 c.c., in the generating flask should be maintained as uniform as possible during the currency of the experiment, increments of water being

added by the funnel when needed. The flask should be kept cool. Standard mirrors are prepared from known amounts of arsenious oxide under precisely similar conditions.

3. *Gutzeit's Test.*—This test, as originally suggested and carried out by its proposer, consisted in the generation of hydrogen arsenide from an arseniferous material by means of zinc and hydrochloric acid, and passing the gas so liberated upon or against a piece of bibulous paper moistened with a solution of silver nitrate. While this silver salt possesses the advantage of being very sensitive to this gas, it unfortunately has the very considerable disadvantages that it is most readily darkened by exposure to the light, and also is very readily affected by the presence of sulphuretted hydrogen, which is sometimes apt to be present, or to be generated from sulphur compounds during the operation of the process. Accidental presence, therefore, of sulphuretted hydrogen gas when testing for hydrogen arsenide destroyed the accuracy and value of the test. It was for this reason that mercuric chloride solution was substituted in place of the silver salt, and although it is not so rapidly sensitive to the arsenical gas as the silver salt, it is, when precautions are taken to eliminate the H_2S, a surer indication of the presence of arsenic when a reaction does take place on the mercuric chloride test-paper. It must be noted, however, that mercuric chloride paper is not likely to show evidence of staining by the sulphur gas unless it be present in sufficient quantity to produce a distinct reaction with lead acetate paper. The weak part of the original test, therefore, consisted in the possible reaction with that gas, consequently the presence of sulphides or sulphites in the substance to be examined militated seriously

against the accuracy of the test, unless special precautions were taken. When these compounds were suspected to be present in the material to be examined, it was found necessary to oxidise them by the careful addition of iodine or bromine solution. The effect of the arsenical gas upon a dried spot of mercuric chloride on paper is the production of a yellow coloration on the previously colourless spot, the depth of the yellow tint depending upon the amount of arsenic present, but it varies from a lemon-yellow, through a bright yellow, to an orange-yellow tint.

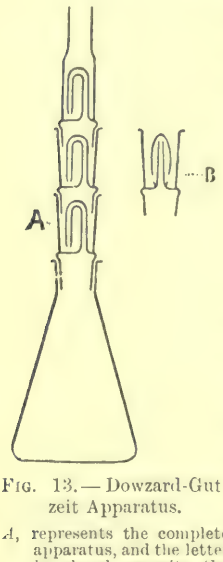

FIG. 13.—Dowzard-Gutzeit Apparatus.

A, represents the complete apparatus, and the letter is placed opposite the first cell containing absorbent solution. *B* shows one of the cells separate.

It will be obvious from what has been said, that this test, which is more sensitive than those of Reinsch and Marsh for minute amounts of arsenic, would be practically perfect for the discovery of such minute amounts of this poison as are likely to exist in the excretions of persons or in the organs of the bodies of those affected noxiously by hydrogen arsenide, were an apparatus arranged or constructed whereby adventitious gases could be arrested and eliminated before they could act upon the sensitive mercury spot. Such an apparatus and method of use have been devised by Dowzard.[1] The text of the communication is accompanied by a sketch of the apparatus, which we reproduce (Fig. 13). The principle of the apparatus is to generate hydrogen gas and to arrest or trap in

[1] *Journ. Chem. Soc.* vol. lxxix. and lxxx. p. 715.

neutralising chemical solutions those gases which would interfere with the integrity and accuracy of the result of the test. The apparatus itself consists essentially of an Erlenmeyer flask, and of cells for washing any adventitious gases, the latter being fitted into the flask after the fashion of a series of superposed hollow stoppers. Dowzard himself describes the mode of using the apparatus as follows:—"A weighed or measured portion of the sample is mixed with 5 c.c. of pure hydrochloric acid (if the sample is alkaline, it must first be neutralised), four drops of a 15 per cent solution of cuprous chloride in hydrochloric acid are then added, and the mixture made up to 30 c.c. with water; if it is not convenient to work with such a small bulk as 30 c.c., this quantity may be doubled or trebled, but the same proportion of acid should be used. A rod of pure zinc, 3 cm. long and 5 mm. in diameter, is first placed in the flask, the above mixture is then introduced, and the first cell placed in position; lead acetate solution (5 per cent) is now poured into the cell until it is about half full, the second and third cells are filled in a similar manner, a small tuft of cotton wool is introduced into the neck of the top cell and its mouth capped with mercuric chloride paper, which may be held in position by an elastic band or a glass collar made from a piece of glass tubing. After forty minutes or more, the cap is removed and examined in full daylight. A minute trace of arsenic is indicated by a lemon-yellow spot, which varies in tint according to the amount present, and a heavy trace by an orange-brown spot. The mercuric chloride paper is prepared as follows. One drop of a 5 per cent solution of mercuric chloride is allowed to fall on the centre of a piece (4 cm. square) of thin, Swedish filtering paper such as Muncktell's No. 1 F: the paper is dried before using."

Used in the above manner, sodium sulphite and sodium hypophosphite were tested in the apparatus; it was found that the lead solution completely absorbed the H_2S from the former, but did not prevent the phosphuretted hydrogen from the latter from passing to stain the mercuric paper; but by placing in the other cells a 15 per cent solution of cuprous chloride in hydrochloric acid, this latter gas was also prevented from passing to cause a stain.

The cuprous chloride solution is prepared in the following way, viz.:—Dissolve 16 grammes of pure cupric oxide in 110 c.c. of pure hydrochloric acid. To this solution add 13 grammes of pure thin "electric" copper foil cut into small pieces, and boil for 25 minutes. Then pour the resulting solution of cuprous chloride into 1000 c.c. distilled water, and wash the white precipitate by decantation. Dissolve the washed precipitate in arsenic-free hydrochloric acid; evaporate to dryness 5 c.c. of the solution; weigh the residue; and from the result, dilute the bulk of the solution with hydrochloric acid until 100 c.c. contains about 15 grammes of cuprous chloride.

With the cells charged as described, 0·000005 gramme of arsenious acid was added to the apparatus, when the mercuric cap was stained a faint yellow colour. From his experiments, therefore, Dowzard concluded that the use of lead acetate and of cuprous chloride solutions do not interfere with the passage of arseniuretted hydrogen, but effectually stop the passage of the other gases. Moreover, he tested the value of the apparatus in respect of antimoniuretted hydrogen. He found, by using amounts of potassium antimonium tartrate up to 0·10 gramme and washing the gas produced three times (*i.e.* through the three cells) with the cuprous chloride solution, that in no case was a stain produced on the mercuric cap; but when

the amount was increased to 0·2 gramme, that a faint blackish-brown stain was formed. From the foregoing, then, Dowzard concludes that arsenic can be detected even in presence of about 2500 times its weight of antimony. He recommends further that, when antimony is present, the proportion of hydrochloric acid to be used should be 1 in 8, and that only one drop of cuprous chloride should be used, so that it may limit the rapidity of the evolution of the hydrogen, and, at the same time, enable the cuprous chloride in the cells to exercise its full absorbing effect. The presence of selenium and tellurium compounds, he affirms, does not interfere with the usefulness of his method.

For testing samples of glucose by this method, some of which contain sulphites in comparatively large amounts, he recommends that a slight excess of bromine water be added to the mixture, and that the mixture should thereafter be heated until it is bromine-free; and that after the solution is cooled, 8 c.c. of the acid and 4 drops of the cuprous solution should be added, and the mixture thereafter made up to 40 c.c. with water. In order to make this test of value for quantitative estimations, he recommends that careful attention should be given to the following points, viz.:—(1), that parallelism with respect to amounts of reagents and temperature of experiments be maintained in every particular; (2), that the reaction should occupy the same exact time; (3), that the colour stain produced from a given sample be carefully compared with the colour of the stains produced from known standard amounts of arsenious acid; and (4), that exactly duplicate apparatus be used. He declares that if a yellow stain is formed on the mercuric cap by any substance which has been treated in the foregoing manner, the

evolving gas having been passed through the cuprous solution, the stain is unquestionably due to arsenic, because under these conditions there is no other substance which is able to cause this reaction.

Another modified Gutzeit apparatus has been suggested and devised by Kirkby, which has been called the Kirkby-Gutzeit apparatus,[1] a figure of which we reproduce, Fig. 14. Mr. Kirkby gave evidence before the Royal Commission on Arsenical Poisoning, and his evidence is contained in the first volume of evidence and in the questions and answers, 3628-3833. Moreover, in the book published jointly by Kelynack and himself,[2] he gives the results of his experience with his modified Gutzeit test. Instead of the silver nitrate used in the former, he adopted the use of the mercuric chloride filter-cap. He stated before the Commission that of all the tests for arsenic the Gutzeit test, as modified by him, was the most satisfactory in his hands (Q. 3663). When asked how, in view of the fact that the Gutzeit test was not essentially a quantitative test, he translated his results obtained by that test into quantitative amounts, he replied that he had a set of standard colour stains obtained from different known amounts of arsenious acid with a given quantity of acid, a given amount of zinc, and operating for a given time; in other words, with a definite volume of sulphuric acid, and a definite amount of zinc, both arsenic-free, and after introducing a known amount of arsenious oxide, he obtained after a given time a certain definite colour stain; and so on, with varying known amounts of the arsenious oxide. Latterly, however, instead of operating for a given time with these reagents, he adopted the plan of using a

[1] *Pharm. Journ.* Jan. 26, 1901, p. 80.
[2] *Arsenical Poisoning in Beer Drinkers*, 1901.

given quantity of zinc and a given volume of sulphuric acid just sufficient to dissolve the zinc. He says, "At the present time, I think it better to use a given weight of zinc, and submit that to the action of a given weight or volume of sulphuric acid, and allow the gas to pass through the bulbs of the apparatus until it [the zinc] is dissolved." (Q. 3676.) When further asked, since the result of the test is only an approximation to a quantitative test, whether for legal purposes that fact would not invalidate the test owing to the element of indefiniteness, and in respect that probably no two persons would entirely agree upon the amount present from the colour of the stain produced, he said that, in his opinion, if the test were carried out in a definite manner the judgment formed would be fairly definite, and that, so far as his experience went, he "had greater confidence in coming to a conclusion as to the amount of arsenic present as exhibited in the test papers" than he "had from examining the mirrors seen in the Marsh-Berzelius tube, and greater confidence than he has had in examining the sublimates obtained from the copper in Reinsch's test when the proportion was small."

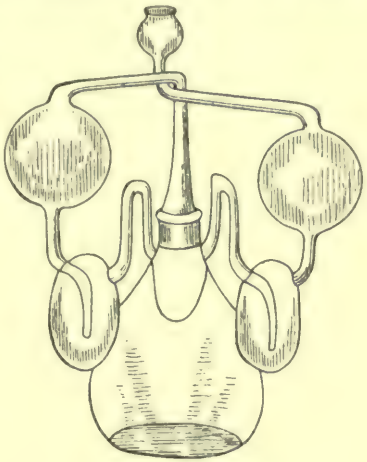

FIG. 14.—Kirkby-Gutzeit Apparatus.

The arrangement of absorbent cells, it will be noted, differs from that in Fig. 13, but their object and action are identical.

Preparation of Animal Substances for Detection of Arsenic in Foregoing Tests.—Before animal substances can be subjected to the Marsh-Berzelius or other tests in which nascent hydrogen plays an important part, it is absolutely necessary that they should undergo preparatory treatment. There are two prominent methods, at least, whereby that may be done, viz.:—(1) the method of Fresenius-Babo, and (2) the method of Gautier. These demand some detailed consideration. Full details of these are to be found in the Report of the Royal Arsenical Commission.[1]

1. *Fresenius-Babo Method.*—The principles of the method are that animal tissues, when pulped or otherwise broken down, and after treatment with strong hydrochloric acid and potassium chlorate, are reduced to a state of solution. The method, however, takes not a little time, especially when relatively large amounts of animal material have to be treated. Moreover, careful attention must be given to the entire details of the process.

Details of Process.—A convenient weight of tissue is taken: in the case of viscera, for example, from 100 to 150 grammes. The weighed amount is cut up into small pieces and pulped, as far as may be, in a mortar. It is then put in a Berlin porcelain basin with about three times its volume of water, and hydrochloric acid of 1·10 sp. gr. added. The amount of acid to be added will vary according to the actual weight taken, but from 20 c.c. to 70 c.c. are about the limits. The mixture is now thoroughly stirred, and thereafter is warmed over a low burner almost, but not quite, to boiling. Pure powdered potassium chlorate is added from time to time in large pinches at intervals of a few minutes. During this process,

[1] *Report of Evidence*, vol. ii. App. xxii.

the liquid in the basin is kept constant in amount by the addition, when required, of water. Eventually the whole of the solid material passes into solution, and the liquid which remains is of a yellow colour. Small pinches of the chlorate are added during the process until the yellow colour of the liquid ceases to change to a brown colour after ten minutes' interval, after which the liquid is kept warm until it just begins to darken in colour, this being the indication that all the added chlorate has been decomposed. The liquid is now permitted to cool completely, or it may more rapidly be cooled artificially by the aid of cold water or ice in which the basin may be placed. The effect of the cooling is that a large amount of solid matter separates out at the bottom of the basin. The clear supernatant liquid is then poured into a filter of Swedish filter-paper, when, if the filtration be properly conducted, a clear filtrate will be obtained. The residue in the basin is washed three or four times by being warmed with water which has been acidulated with hydrochloric acid, and is cooled each time before being filtered. The original filtrate and the filtrates from the washings are now mixed, and are slowly evaporated over a small rose flame to a volume of about 200 c.c., a crystal of chlorate being added from time to time should the liquid darken in colour. The fluid is now cooled, and from 10 c.c. to 15 c.c. of a saturated aqueous solution of suphurous acid are added, to reduce any arsenic which may be present to the arsenious condition. The mixture should now be allowed to stand for at least two hours. Thereafter by quiet evaporation the sulphurous acid is driven off, care being taken that sufficient concentration of the fluid does not occur so that arsenic trichloride, which is volatile, is formed. The liquid remaining from the

foregoing processes should now amount to between 150 and 200 c.c. in volume. It is now completely cooled, and, if necessary, is filtered into a conical Jena glass flask of about 200 c.c. capacity. Through the liquid now in the flask a slow current of washed sulphuretted hydrogen is passed for an hour, the flask is then stoppered tightly, and is placed in a moderately warm place for about 24 hours. At the end of this time, H_2S is again passed through the liquid, and the flask, again stoppered, is put back in the warm place for two days. If at the end of this period the liquid smells strongly of the H_2S, it is filtered through purified asbestos in a Gooch crucible, the precipitate being washed with H_2S water in small quantity, else, as M'Gowan and Finlow remark, otherwise the As_2S_3 is apt to assume the colloidal form and pass through the filter. The asbestos with the washed precipitate is then transferred to a small porcelain basin, the crucible being rinsed with a little water. The basin and contents are then warmed on a water-bath to separate the asbestos, and 2·5 c.c. of 1 in 5 aqueous ammonia are added, the warming being continued for a little longer. The dark-coloured liquid is now poured from the asbestos on to a small Swedish filter, extraction being continued with small amounts of the aqueous ammonia until both asbestos and filtrate are colourless. Arsenic, if present, is now in the filtrate. The filtrate is now evaporated to dryness on a water-bath, to expel all the ammonia. Two c.c. of strong nitric acid are now added to the residue, and the mixture kept digesting on the bath, with small added amounts of nitric acid, not exceeding 1 c.c. at a time, until the liquid is yellow in colour. Any free nitric acid is now evaporated off, and the residue is extracted three or four times with 5 c.c. to 10 c.c. of a 1 in 4 watery solution of ammonium

carbonate, in order to get rid of sulphur. The whole is now filtered, and the filtrate evaporated on a water-bath till free from ammonia. Treat again the residue with nitric acid, and once more evaporate to dryness. Now add about 10 drops of strong sulphuric acid, and heat the basin until the contents are thoroughly charred, when excess of acid is driven off, taking care that no part of the basin becomes red-hot, and that heating is stopped as soon as fumes of sulphurous acid begin to escape. The dry, pulverisable, charred product is now extracted several times with water acidulated with sulphuric acid and filtered after each extraction. To the filtrate, which ought to be clear, colourless, and without smell, add a few drops of aqueous sulphurous acid, steam off excess of sulphurous acid, and the liquid is now ready for use in the Marsh-Berzelius or other kindred process.

2. *Gautier's Method.*—This method is applicable also to animal matter, and is particularly serviceable where small amounts of animal matter have to be treated. The principles of the method are the destruction of the organic matter by oxidation with concentrated nitric acid, and charring the residue with strong sulphuric acid, driving off excess of the latter, and extracting the residue with water acidulated with sulphuric acid.

Details of Process.—The animal matter having been divided into a fine condition by mincing or pulping, a known weight is used. For every 10 grammes of material used and placed in a porcelain basin, 5 c.c. of strong nitric acid are added in the cold. Then the basin and contents are heated cautiously on a water-bath. After frothing has ceased, the heating may be increased, and small quantities of nitric acid added from time to time until the whole of the material goes into solution. Thereafter the basin and

contents are heated on a *dry* water-bath until the mass is semi-solid or pasty, when 1 c.c. of strong sulphuric acid for every 10 grammes of material used is added, and the heating continued until the mass becomes black. The basin may now be placed on a pipe triangle, and heating from an ordinary Bunsen flame applied cautiously to drive off excess of acid. Exactly similar precautions must be taken at this stage as in the former process regarding heating of basin and escape of sulphurous acid; and the succeeding steps are exactly alike to those in the previous process in order to obtain a clear, colourless, inodorous filtrate for use in the Marsh-Berzelius or other like process.

CHAPTER XVI.

BIBLIOGRAPHY.

THE task of bringing together all the recorded cases of poisoning by this gas has involved no little labour, in respect that the cases are scattered throughout the medical literature of this and other countries. It is true that from time to time attempts have been made to collect cases, the records assuming either the form of articles to medical magazines, or in a more ambitious form, as inaugural theses for the doctorate degree of a foreign University. In this latter form much more attention has been paid to intoxication by this gas by Continental than by British writers. Of the principal theses which we have been able to discover, the following in chronological order are probably the most important: certainly very diligent search has failed to reveal any others.

Jacob Becker published in Giessen in 1888 an inaugural dissertation, in which he gives epitomised accounts of the cases numbered in our pages I. to VII. inclusive and Cases XI., XII., XIII., and XX., and adds a full account of the symptoms and post-mortem appearances of Case XXI., which occurred in Giessen in 1885.

Earlier in the same year, Carl Dütting also published a thesis in which, while giving some small attention to the incidence of occupation of persons who had been

poisoned by inhalation of the gas, he gives particulars of the symptoms, etc., of the six Italian pedlars who were simultaneously attacked while engaged in filling toy-balloons with hydrogen gas, and which we have recorded under Case XX. (*vide* p. 132).

Perhaps more important than either of these is the thesis of Eduard Geigy which was published at Basle in 1890. The author gives a short historical description of this form of poisoning, together with a brief account of the chemistry of the subject. He considers at some length the symptoms betrayed by animals who had been experimentally subjected to the effects of the gas, and the results upon the blood and bodily organs, together with the mechanism of production of the icterus and hæmoglobinuria. He gives brief but fairly full notes of the cases numbered in our pages I. to XVII. inclusive, but does not include the fresh cases recorded in the previous two theses. He discusses the pathological appearances found in the bodies of those who had died from the effects of the gas, the mode of operation of the gas on the blood and organs of the body, its etiology, diagnosis, prognosis, and treatment. He appends two Tables. In the first he tabulates the occupations of those affected in the cases narrated, the nature of the work in which they were engaged when poisoned, the deaths and recoveries, and other facts, and in the second analyses the incidence of the symptoms exhibited during life.

Next in point of time is the thesis of Ernest Lucas which was published in Paris in 1895. This writer considers the subject under the following heads, viz. :—(*a*) history, (*b*) general considerations, (*c*) symptomatology, (*d*) experiments on animals, (*e*) disturbance of function of liver and kidneys, (*f*) relation of the gas to professional hygiene,

and (*g*) treatment. He summarises somewhat fully the facts of the Cases numbered respectively IV., IX., X., XIII., XV., XVI., and XXIX., but makes no mention of other recorded cases before the date of publication of his thesis.

The most important contribution to the magazine literature of the subject in this country is that by Dixon Mann and Clegg, in which an exhaustive account is given of symptoms and post-mortem appearances of five persons, chemical workers, who were attacked by this gas.

Durand has drawn attention to certain cases of poisoning which occurred in connection with the inflation of military balloons. After a critical consideration of the risks to men employed in inflating and deflating balloons, he indicates how such risks are apt to be induced from the military instructions laid down for such work. For example, he quotes one instruction or regulation respecting particularly the deflation of balloons after free ascents, which reads as follows:— "Practical Instruction respecting Military Air-Balloons. The aeronaut shall station at the orifice three or four willing persons, recommending them not to be disturbed by the odour which escapes, and not to leave their posts; he shall proceed in the same way with regard to the appendix." As remedies, he indicates that the most obvious one is the employment of acids and metals which are arsenic-free, and he further adds that, owing to the undoubted danger, men so employed should be explicitly warned, and in addition that those men who are stationed near the point of filling should be provided with masks which would prevent the respiration of the arsenical gaseous impurity and at the same time permit the inhalation of pure air. This writer is inclined to attribute the comparative frequency of attack in such an

employment to the common habit of the men of smelling from time to time the end of the pipe from which the generated gas emanates, whereby they are apt to inhale the gas. These repeated sniffs, although each takes only a momentary time, permit sufficient of the arsenical gas to be inhaled as to produce marked toxic symptoms. He quotes Maljean to agree with him as to the need, when balloons are about to be filled with hydrogen gas, that the gas should be chemically tested, and for that purpose a piece of filter paper saturated with a strong solution of silver nitrate should be placed over the mouth of the influent pipe. If arseniuretted hydrogen be present, the paper will show black stains due to either reduction of the silver or the formation of the sulphide, and some stains of a brick-red colour due to the formation of arseniate of silver. He cites certain cases from other observers, viz. :— Crone, Granjux, Maljean, and Oulmont, to which we have made allusion in the text. He gives a fairly full description of the cases recorded by Crone, which we have summarised in Case XXXV., but gives only sparse particulars of the others.

The remainder of the recorded cases form isolated contributions to different medical journals. Of these the only one to which, perhaps, allusion ought to be made is that by Ludwig Vanino, in which the writer giving a short account of the history of the discovery of the gas, indicates from experiments from what small amounts of arsenious oxide added to different metals mirrors of arsenic may be obtained by Marsh's process. He mentions more or less briefly some of the facts of the cases numbered in our series I., III., IV., VII., XI., XII., XX., and XXI., and gives a reference to a discussion on three cases of poisoning by the gas in which three Italian pedlars engaged in generating

hydrogen from zinc and sulphuric acid for the purpose of filling toy-balloons (Case XL.).

The remaining thesis to which a reference has been discovered in the course of our search is one published in Dorpat in 1891 by B. Köppel, but we have failed entirely to obtain possession of a copy, and are therefore unable to say anything regarding its contents.

APPENDIX.

TABLE I.

SHOWING (*a*) OBSERVATIONS, (*b*) NAME OF RECORDER, (*c*) NUMBER OF CASES, (*d*) OCCUPATIONS OF THOSE ATTACKED, (*e*) RECOVERIES, (*f*) DEATHS, AND (*g*) TIME OF DEATH AFTER EXPOSURE TO GAS, IN CHRONOLOGICAL ORDER IN POISONING BY ARSENIURETTED HYDROGEN.

Number of Observation.	Name of Recorder.	Number of Cases.	Occupations of Attacked.	Recoveries.	Deaths.	Time of Death after Exposure.
I.	Ruhland (1815)	1	Chemist	0	1	9th day
II.	Schindler (1836)	1	Pharmacist	1	0	
III.	Taylor (1836)	1	Chemist	0	1	24th day
IV.	O'Reilly (1841)	1	,,	0	1	7th day
V.	Mouat (1850)	1	Professor of Chemistry	1	0	
VI.	Vogel (1851)	1	Lecturer on Physics	1	0	
VII.	Ollivier (1863)	1	Chemist	0	1	5th day
VIII.	Chevallier (1863)	1	,,	1	0	
IX.	Valette (1870)	2	,,	0	1	30th day
			Mechanic	1	0	
X.	Ollivier (1872)	2	Professor of Physics	1	0	
			Assist. Professor of Physics	1	0	
XI.	Trost (1873)	9	Works Manager	1	0	
			Workman	0	1	2nd day
			,,	0	1	3rd day
			,,	0	1	6th day
			,,	1	0	
			,,	1	0	
			,,	1	0	
			,,	1	0	
			,,	1	0	
XII.	Wachter (1878)	4	Toy-balloon Maker	0	1	10th day
			,,	1	0	
			,,	1	0	
			,,	1	0	

XIII.	Eitner (1879)	4	Professor of Physics	1	0	
			,,	1	0	
			Student	1	0	
			,,	1	0	
XIV.	Coester (1884)	1	Chemical Worker	0	1	9th day
XV.	Von Sury-Bienz	5	,,	1	0	
			,,	1	0	
			,,	1	0	
			,,	1	0	
			,,	1	0	
XVI.	Geigy (1887)	1	,,	0	1	7th day
XVII.	Geigy (1887)	1	,,	1	0	
XVIII.	Martineau (1871)	1	Druggist	0	1	3rd day
XIX.	Freer (1885)	6	Child (from wall-paper)	1	0	
			,,	1	0	
			,,	1	0	
			,,	1	0	
			,,	1	0	
			,,	1	0	
XX.	Dütting (1888)	6	Toy-balloon Maker	0	1	6th day
			,,	0	1	3rd day
			,,	1	0	
			,,	1	0	
			,,	1	0	
			,,	1	0	
XXI.	Becker (1888)	1	Chemist	0	1	3rd day
XXII.	Wolverhampton Cases (1889)	2	Chemical Worker	0	1	2nd day
			,,	1	0	
XXIII.	Schickhardt (1891)	1	Chemist	1	0	
XXIV.	Storch (1892)	1	Balloonist	1	0	
XXV.	Llanelly Cases (1892)	3	Chemical Worker	0	1	7th day
			,,	0	1	10th day
			,,	1	0	
XXVI.	Danish Case (1892)	1	Not known	Not known	Not known	Not known
XXVII.	Martin (1893)	1	Chemical Worker	0	1	6th day
XXVIII.	Luff (1895)	1	Professor of Chemistry	0	1	5th day

TABLE I.—*Continued.*

Number of Observation.	Name of Recorder.	Number of Cases.	Occupations of Attacked.	Recoveries.	Deaths.	Time of Death after Exposure.
XXIX.	Strassman (1895)	1	Chemical Worker	0	1	3rd day
XXX.	Lucas (1895)	3	Student	1	0	
			,,	1	0	
			Professor of Physiology	1	0	
XXXI.	Dixon Mann and Clegg (1895)	5	Chemical Worker	0	1	6th day
			,,	0	1	7th day
			,,	1	0	
			,,	1	0	
			,,	1	0	
XXXII.	Gulewitsch (1898)	1	Chemist	1	0	
XXXIII.	Clayton (1901)	10	Chemical Worker	0	1	7th day
			,,	1	0	
			,,	1	0	
			,,	1	0	
			,,	1	0	
			,,	1	0	
			,,	1	0	
			,,	1	0	
			,,	1	0	
			,,	1	0	
XXXIV.	Maljean (1900)	3	Military Balloonist	1	0	
			Lieutenant	1	0	
			,,	1	0	
XXXV.	Maljean (1900)	3	Military Officer	1	0	
			Sergeant	1	0	
			Military Officer	1	0	
XXXVI.	Crone (1900)	2	Soldier	0	1	3rd day
			,,	0	1	5th day
XXXVII.	Granjux (1900)	5	Soldier-balloonist	0	1	Almost immediately
			,,	0	1	6th day
				1	0	

			Soldier-balloonist	1	0	
			,,	1	0	
XXXVIII.	Oulmont (1889-90)	2	Balloonist	0	1	Not known
			Peasant	0	1	,,
XXXIX.	*New York Med. Rec.* (1900)	1	Aeronaut	Not stated	Not stated	Not stated
XL.	Breslau Cases (1901)	3	Italian Toy-balloon Pedlar	1	0	
			,,	1	0	
			,,	1	0	
XLI.	Author (1901)	3	Chemical Worker	0	1	6th day
			,,	1	0	
			,,	0	1	Not known
XLII.	Factory Report, 1901	7	Galvaniser	1	0	
			,,	1	0	
			,,	1	0	
			,,	1	0	
			,,	1	0	
			,,	1	0	
			,,	1	0	
XLIII.	*Chem. Industrie* (1903)	3	Plumber	0	1	Almost immediately
			,,	0	1	2nd day
			,,	0	1	3rd day
XLIV.	Factory Report, 1905	1	Chemical Worker	1	0	
XLV.	Factory Report, 1906	3	Worker in electrical recovery of Copper	1	0	
			,,	1	0	
			,,	1	0	
XLVI.	Home Office (Dr. Legge)	2	Recovery of Gold	1	0	
				0	1	Not stated
XLVII.	,, ,,	1	Cleaning of Sulphuric Acid Tank	0	1	Not stated
	Total	120		81	37	
				In two cases result not known.		

NOTE.—Of the total 120 cases, the fate of two cases was not known to the author. This leaves 118 cases of which the results are known, and of these 81 recovered and 37 died.

TABLE II.

Number of Observation.	Cause of Poisoning.	Time of Onset of Symptoms.	Time of Exposure to Gas.	Initial Symptoms.	Hæmoglobinuria.	Jaundice. Characters.	Oliguria.	Anuria.
I.	Evolution of gas from Arsenic and Potash	About one hour	Short	Vomiting, shivering, great weakness	Present	Not stated	Not stated	Not stated
II.	Evolution of gas	Four hours	Two hours	Pain in loins, shiverings, pain in epigastrium, vomiting	Present	Present. Dark-brown	Not stated	Not stated
III.	Evolution of gas	Not stated	Short	Not given	Not stated	Not stated	Not stated	Not stated
IV.	Inhalation of Hydrogen	Immediately	About 150 cubic inches of H gas inhaled	Giddiness, fainting, shiverings, pains in legs	Present	Present. Face, copper-colour; body, greenish-yellow	Present	Present
V.	Demonstration to students of Marsh's process	Within one hour	Few minutes	Burning and constriction of throat, vomiting	Present	Present eighteen hours after	Not stated	Not stated
VI.	Inhalation of Hydrogen	Immediately	Short	Weakness of limbs, fainting, shivering	Present	Not stated	Not stated	Not stated
VII.	Research in Anilin-colours	About one hour	Three hours	Intense headache, severe pain in epigastrium, vomiting	Present	Present. Earthy-coloured	Present	Present
VIII.	Med.-legal Exam. of organs by Marsh's process for Arsenic	Eight to ten hours	Short	Violent headache, shiverings	Not stated	Not stated	Not stated	Not stated
IX.	Accidental substitution of Arsenic Acid for Sulphuric Acid in generating Hydrogen	(1) Some minutes	Short	(1) Sickness and vomiting	Present	Present. Yellowish	Not stated	Not stated
		(2) Longer		(2) ,,	,,	Present. Brown in colour	Present	Present

X.	Inhalation of Hydrogen	(1) Six hours	Short	Hæmoglobinuria	Present	Present. Yellow	Absent	Absent
		(2) Twenty-four hours	,,	,,	,,	,, ,,		
XI.	Extraction of silver from ore with HCl	(1) A few hours	Some hours	Sickness, giddiness, depression	Present	Present	Absent	Absent
		(2) Five hours	,,	Headache, giddiness, vomiting	,,	,,	,,	,,
		(3) Twelve hours	Short time	Not stated	Not stated	Not stated	,,	,,
		(4) ,,	Some hours	Headache, vomiting, etc.	Present	Present	Present	Present
		(5) ,,	,,	,,	,,	,,	,,	,,
		(6) ,,	,,	,,	,,	,,	,,	,,
		(7) ,,	,,	,,	,,	,,	Absent	Absent
		(8) ,,	,,	,,	,,	,,	,,	,,
		(9) ,,	,,	,,	,,	,,	,,	,,
XII.	Filling toy-balloons with Hydrogen generated from Zinc and Sulphuric Acid	(1) About an hour	Half an hour	Giddiness, headache, nausea, etc., trembling of limbs, vomiting, sleeplessness	Present	Present. Colour not stated	Absent	Absent
		(2) ,,	Two hours	,,	,,	Present. Citron-yellow	,,	,,
		(3) ,,	Three hours	,,	,,	Present. Very dark	Present	,,
		(4) ,,	,,	,,	,,	Present. Not stated	,,	
XIII.	Inhalation of Hydrogen	(1) Some hours	Short	Severe shivering, great weakness, general feeling of illness	Present	Present	Absent	Absent
		(2) ,,	,,	,,	,,	,,	,,	,,
		(3) ,,	,,	,,	,,	Absent	,,	,,
		(4) ,,	,,	,,	,,	,,	,,	,,
XIV.	Worker in Anilin factory	Some hours	Some time	Rigors, pain in head and loins	Present	Present. Very marked	Present	Present
XV.	Manufacture of Zinc Chloride	(1) Some hours	Some hours	Sickness, pains in head, vomiting, headache, etc.	Present	Present	Absent	Absent
		(2) ,,	,,	,,	,,	,,	,,	,,
		(3) ,,	,,	,,	,,	,,	,,	,,
		(4) ,,	,,	,,	,,	,,	,,	,,
		(5) ,,	,,	,,	,,	,,	,,	,,
XVI.	Manufacture of Zinc Chloride	Some hours	Some hours	Violent pain in loins, giddiness, headache, shaking of body and limbs	Present	Present. Bronze colour	Present	Present

TABLE II.—*Continued.*

Number of Observation.	Cause of Poisoning.	Time of Onset of Symptoms.	Time of Exposure to Gas.	Initial Symptoms.	Haemoglobinuria.	Jaundice. Characters.	Oliguria.	Anuria.
XVII.	Making Congo-red colour.	Same night	Several hours	Pain in stomach, vomiting, coldness of hands and feet	Present	Present. Brown colour	Absent	Absent
XVIII.	Not known.	Not known	Not known	Constant vomiting, cyanosis, coldness of limbs	Not stated	Not stated	Present	Present
XIX.	From wall-paper	(1) Exposure to arsenical wall-paper in room	Days	Vomiting, tenderness of epigastrium, furred tongue	Absent	Present. Well marked	Not stated	Not stated
		(2) ,,	,,	,,	,,	,,	,,	,,
		(3) ,,	,,	,,	,,	,,	,,	,,
		(4) ,,	,,	,,	,,	,,	,,	,,
		(5) ,,	,,	,,	,,	,,	,,	,,
		(6) ,,	,,	,,	,,	,,	,,	,,
XX.	Filling toy-balloons with Hydrogen Gas	(1) Some hours	Several hours	Feeling of constriction and pains in head, weakness, fainting, vomiting, pains in epigastrium, sleeplessness, great depression	Present	Present. Deep yellowish-grey	Present	Present
		(2) ,,	,,		,,	Present. Very yellow	,,	,,
		(3) ,,	One hour		,,	Present. Marked	Absent	Absent
		(4) ,,	,,		,,	Present	,,	,,
		(5) ,,	Three hours		,,	,,	,,	,,
		(6) Seventeen days	,,		,,	,,	,,	,,
XXI.	Inhalation of Hydrogen Gas	Half an hour	On two separate times	Violent pains in loins, shiverings, vomiting	Present	Present. Bronze colour	Present	Present
XXII.	Utilisation of galvanisers' flux skimmings	(1) Immediately	A few minutes	Unconsciousness, vomiting of blood, etc.	Present	Present. Mahogany colour	Present	Present
		(2) Some hours	,,	,,	,,	Not stated	Absent	Absent
XXIII.	Chemist. Reduction of Nitro-methyl-anilin	Some hours	Two hours	Sudden weakness, faintings, desire to vomit, shiverings	Present	Present. Light yellow	Present	Absent

XXIV.	Filling a captive balloon with Hydrogen Gas	Same day	Some hours.	Giddiness, pains in head, nausea, cardialgia	Present	Present. Peculiar deep-brown	Absent	Absent
XXV.	Dissolving mixture of metals in open vessel with Hydrochloric Acid	(1) Six hours	Ten to fifteen minutes	Diarrhœa, severe abdominal pains	Not stated	Present	Not stated	Not stated
		(2) ,,	,,	,,	,,	,,	,,	,,
		(3) ,,	,,	Not stated	,,	Not stated	,,	,,
XXVI.	Not stated	Not stated	Not stated	Not stated	Not stated	Not stated	Not stated	Not stated
XXVII.	Manufacture of Zinc Chloride	Some hours	Half an hour	Sickness, vomiting, pains in head and loins, sleeplessness	Present	Present. Marked	Present	Absent
XXVIII.	Not ascertained	Not ascertained	Not ascertained	Not ascertained	Not ascertained	Not ascertained	Not ascertained	Not ascertained
XXIX.	Working with Hydrochloric Acid in anilin factory	Not stated	Not stated	Cyanosis, vomiting, etc.	Present	Present. Mulatto colour	Present	Present
XXX.	(1) Making AsH_3 gas	Few minutes	About three hours	Intense headache, vertigo, etc.	Present	Present. Bronze-like	Absent	Absent
	(2) Assisting at do.	One hour	A sniff of gas	Shiverings, sickness, pains in loins	,,	Present. Slight	,,	,,
	(3) Inhalation of Hydrogen	About one hour	Short time	Violent headache, giddiness, sickness	,,	Present	,,	,,
XXXI.	Manufacture of Zinc Chloride	(1) Same night	Several hours	Pain in back, vomiting	Present	Present. Dusky-yellow	Present	Present
		(2) ,,	,,	Pain in back, vomiting, diarrhœa	,,	Present. Ashy dusky colour	,,	,,
		(3) ,,	,,	Malaise, pain in back	,,	Present	Not stated	Not stated
		(4) Same afternoon	Some hours	,,	,,	,,	,,	,,
		(5) Same night	Five minutes	Pains over stomach, vomiting	,,	,,	,,	,,
XXXII.	Dipping a copper plate into mixture of arsenious and other acids and water	One hour	Not stated	Polyuria, etc.	Present	Not stated	Absent	Absent

TABLE II.—*Continued.*

Number of Observation.	Cause of Poisoning.	Time of Onset of Symptoms.	Time of Exposure to Gas.	Initial Symptoms.	Hæmoglobinuria.	Jaundice. Characters.	Oliguria.	Anuria.
XXXIII.	Manufacture of Zinc Chloride	(1) Half an hour	Several hours	Burning pain in throat and stomach, nausea, violent vomiting, diarrhœa	Present	Present. Intense coppery hue	Not stated	Absent
		(2) ,,	,,	,,	,,	,,	,,	,,
		(3) ,,	,,	,,	,,	,,	,,	,,
		(4) ,,	,,	,,	,,	,,	,,	,,
		(5) ,,	,,	,,	,,	,,	,,	,,
		(6) ,,	,,	,,	,,	,,	,,	,,
		(7) ,,	,,	,,	,,	,,	,,	,,
		(8) ,,	,,	,,	,,	,,	,,	,,
		(9) ,,	,,	,,	,,	Present. Not so intense	,,	,,
		(10) ,,	,,	,,	,,	,,	Present	Present
XXXIV.	Military ballooning	(1) Same day	Many hours	Loss of appetite, malaise	Present	Present. Yellow	Not stated	Absent
		(2) ,,	Sniffing the gas	Sickness, great lassitude and weakness	,,	Present. Inclining to olive-green	,,	,,
		(3) About two to three hours	About two to three hours	Sickness, vomiting, colicky abdominal pains and diarrhœa	,,	Present. Greenish-yellow	Present	,,
XXXV.	Military ballooning	(1) Some hours	Sniffing the gas	Giddiness, lassitude	Present	Present. Greenish colour	Not stated	Absent
		(2) ,,	,,	,,	,,	,,	,,	,,
		(3) ,,	Deflation of balloon	Giddiness, lassitude, headache	Not stated	Absent	,,	,,
XXXVI.	Military ballooning	(1) Twenty minutes	Sniffing the gas	Giddiness, constriction in head, dyspnœa, creepy sensations	Not stated	Present. Brownish-yellow	Present	Present
		(2) ,,	,,	,,	,,	,,	,,	,,
XXXVII.	Military ballooning	(1) Almost at once	Escape of gas from balloon	Unconsciousness	Not stated	Not stated	Not stated	Not stated
		(2) ,,	,,	Not stated	,,	,,	,,	,,
		(3) ,,	,,	,,	,,	,,	,,	,,
		(4) ,,	,,	,,	,,	,,	,,	,,
		(5) ,,	,,	,,	,,	,,	,,	,,

XXXVIII.	Military ballooning	(1) Quickly	Escape of gas	Not stated	Not stated	Not stated	Not stated	Not stated
		(2) ,,	Assisting at deflating a balloon	,,	,,	,,	,,	,,
XXXIX.	Balloon inflation	,,	,,	,,	,,	,,	,,	,,
XL.	Filling toy-balloons with Hydrogen Gas	(1) Not stated	Not stated	Not stated	Not stated	Not stated	Not stated	Not stated
		(2) ,,	,,	,,	,,	,,	,,	,,
		(3) ,,	,,	,,	,,	,,	,,	,,
XLI.	Manufacture of bleaching-powder	(1) A few minutes	A few minutes	Sickness, vomiting, etc.	Present	Present. Coppery colour	Present	Present
		(2) ,,	,,	Sickness, shakiness of limbs	Absent	Absent	Absent	Absent
		(3) Not known	Not known	,,	Present	Present	Present	Present
XLII.	"Pickling" in process of galvanising iron	(1) Indefinite	Indefinite	Headache, giddiness, weakness of limbs, tremors	Present in some cases	Present in some cases	Absent	Absent
		(2) ,,	,,	,,	,,	,,	,,	,,
		(3) ,,	,,	,,	,,	,,	,,	,,
		(4) ,,	,,	,,	,,	,,	,,	,,
		(5) ,,	,,	,,	,,	,,	,,	,,
		(6) ,,	,,	,,	,,	,,	,,	,,
		(7) ,,	,,	,,	,,	,,	,,	,,
XLIII.	Soldering a pipe with Hydrogen flame	(1) An hour or more	An hour or more	Not given	Not given	Not given	Not given	Not given
		(2) ,,	,,	,,	,,	,,	,,	,,
		(3) ,,	,,	,,	,,	,,	,,	,,
XLIV.	Manufacture of Zinc Sulphate	Half an hour	Half an hour	Sickness and vomiting, etc.	Present	Present. Coppery	Present	Absent
XLV.	Process for recovery of copper (galvanic)	(1) Not stated	Not stated	Dizziness and collapse	Present	Present	Present	Absent
		(2) ,,	,,	,,	,,	,,	,,	,,
		(3) ,,	,,	,,	,,	,,	,,	,,
XLVI.	Precipitation of gold from Bismuth Chloride	(1) Not stated	Not stated	Vomiting, great exhaustion	Present	Not stated	Not stated	Not stated
		(2) ,,	,,	,,	,,	,,	,,	,,
XLVII.	Cleaning out Sulphuric Acid tank	Not stated	Not stated	Vomiting, malaria	Present	Present	Present	Present

TABLE III.

Post-Mortem Appearances.

No. of Observation.	Brain.	Colour of Skin of Abdomen.	Lungs.	Pleuræ.	Heart.	Liver.	Gall-bladder.	Kideys.	Stomach.
IV.	Normal	Slightly greenish	Collapsed; natural in structure	Contained two pints of reddish-brown fluid	Pale and flabby; cavities empty. Pericardium held a little fluid	Normal in size; deep-indigo in colour	Distended	Deep indigo in colour	Empty. Two inflammatory patches on greater curvature
VII.	Normal	Not stated	Congestion	Not stated	Ventricles contained voluminous clots, partly fibrinous	Congested; no alteration in hepatic cells	Not stated	Enlarged; violet in colour	Contained greenish fluid
XI.	(4) Dura-mater anæmic; pia-mater congested	Dirty-yellow	Mucous membrane of trachea and larynx of greenish-yellow colour	Not stated	Left ventricle empty; right auricle contained a little blood	Moderately enlarged, but not congested; greenish-yellow in colour	Half-full	Much congested, but firm; dark-red in colour	Not stated
	(5) ,,	Yellowish	Not stated	,,	,,	Normal; yellowish-brown in colour	Full	Normal in size; very hyperæmic; dark red in colour; on section, brownish-black in colour	,,
	(6) ,,	Bluish-green	,,	,,	,,	Enlarged; anæmic; soft; slaty-blue in colour	Very full	Normal in size; very hyperæmic; dark red in colour	,,
XIV.	Not stated	Not stated	Not stated	Not stated	Not stated	Firm; not enlarged. Found to contain arsenic	Not stated	Enlarged; black and decomposed	Not stated

XVI.	Membranes anæmic and œdematous. Right lat. ventricle contained clear fluid. Brain substance anæmic	Pale yellow	Collapsed; œdematous	Not stated	R.A. contained a little dark blood; R.V., some dirty brownish-red fluid. Fatty in patches	Enlarged; greyish-brown in colour; pigment found in cells	Full of greenish fluid	Left, chocolate colour; almost black on section. Right, brown in colour; both enlarged	Not stated
XVIII.	Membranes inflamed; substance hyperæmic	Not stated	Not stated	Not stated	Not stated Hæmorrhages in pericardium and endocardium	Fatty. Arsenic found	Not stated	Hyperæmic; cloudy swelling	Arsenic found
XX.	(1) Brain substance yellow in colour	Pale yellow	Not stated	Not stated	Heart muscle a little fatty	Yellow	Distended	Swollen and dark red in colour. Tubules full of red corpuscles	Not stated
	(2) Dura mater greyish-red	Not stated	Not stated Mucous membrane of trachea and bronchi greyish-red in colour	Contained dark blood	Some very dark blood in pericardium; heart flaccid, contained very little blood. Endocardium greyish-red in colour	Swollen. Yellow	Distended with greenish-black contents	Swollen; reddish-black in colour	Not stated
XXI.	Not stated	Dark yellow or coffee-coloured	Collapsed	Left cavity contained ½ of a litre of brownish-red fluid; right cavity, the same	Pericardium contained moderately large amount of similar fluid. All chambers contained ante-mortem and post-mortem clots. L.V. fatty	Enlarged; on section marbled in yellowish-brown and brownish-red colours	Distended with dark green bile	Enlarged; on section dark in colour	Nothing unusual
XXII.	Not stated	Mahogany colour	Not stated	Not stated	Not stated	Green colour Found to contain arsenic	Not stated	Green colour Found to contain arsenic	Not stated
XXVIII.	Not stated Tissues of body found to be in state of fatty degeneration	Not stated	Not stated	Not stated	Not stated	Not stated	Not stated	Not stated	Not stated

TABLE III.—*Continued.*

No. of Observation.	Brain.	Colour of Skin of Abdomen.	Lungs.	Pleurae.	Heart.	Liver.	Gall-bladder.	Kidneys.	Stomach.
XXIX.	Not stated	Greyish-yellow	Brownish in colour	Not stated	Brownish in colour	Brownish in colour	Not stated	Brownish in colour	Not stated
XXXI.	(1) Normal but anæmic	Two oval discoloured patches on sides of abdomen	Emphysematous at apices, and congested and œdematous at bases	Both contained small quantity of fluid coloured as if stained with bile. Visceral and parietal pleurae deeper violet colour than usual	Pericardium contained 3 oz. of fluid of colour as of bile-staining. All chambers of heart had ante-mortem and post-mortem clots	Large; normal in colour Arsenic found	Full. Arsenic found	Both very much swollen; on section dark red Arsenic found	Mucous membrane gelatinous, and showed petechiæ
	(2) Normal	Ashy dusky colour	Œdematous and congested	Small quantity of fluid in each	Pericardium contained 1½ oz. of fluid. Heart enlarged; clots as in No. 1	Enlarged; normal in colour. Fatty degeneration in areas Arsenic found	Not stated	Both swollen and congested Arsenic found	Deeply congested; petechiæ over whole mucous surface
XXXVI.	(1) Anæmic	Brownish-red	Œdema of bases	Not stated	L.V. some thin, elongated clots. R.V. clots more numerous	Enlarged; yellowish; fatty	Not stated	Congested	Not stated
	(2) ,,	,,	,,	,,	,, Arsenic found	,, Arsenic found	,,	,, Arsenic found	,, Arsenic found
XLI.	Brain and membranes healthy	Yellowish	Emphysematous along anterior margins. Bases engorged and œdematous	Normal	L.V. slightly hypertrophied; otherwise normal	Slightly enlarged; colour normal Arsenic found	Distended	Slightly enlarged; dark-red in colour Arsenic found	Normal size; empty, mucous membrane slaty-grey in colour

TABLE IV.

Showing the Conditions of the Blood, Urine, and Bowels.

Number of Observation.	Condition of Blood-Corpuscles.	Blood Spectrum.	Condition of Urine.	Condition of Bowels.
I.	Not stated	Not stated	Bloody	Not stated
IV.	Not stated	Not stated	Bloody	Loose. Diarrhœa later
V.	Not stated	Not stated	Bloody	Clayey stool with slough
VI.	Not stated	Not stated	Bloody ; albumin ; no red corpuscles	Not stated
VII.	Not changed	Not stated	Bloody ; albumin ; no red corpuscles	Foul and copious stools
IX.	(1) Not stated	Not stated	Bloody	Not stated
	(2) ,,	,,	,,	Bloody stools
X.	(1) Not stated	Not stated	Bloody	Bloody stool
	(2) ,,	,,	,,	Not stated
XI.	(1) Not stated	Not stated	Bloody	Blood-coloured stool
	(2) ,,	,,	,,	Open
	(3) ,,	,,	Not stated	Not stated
	(4) ,,	,,	Bloody	Liquid stool
	(5) ,,	,,	,,	Dark-brown stool
	(6) ,,	,,	,,	,,
	(7) ,,	,,	,,	,,
	(8) ,,	,,	,,	,,
	(9) ,,	,,	,,	,,

TABLE IV.—*Continued*

Number of Observation.	Condition of Blood-Corpuscles.	Blood Spectrum.	Condition of Urine.	Condition of Bowels.
XII.	(1) Shrivelled	Not stated	No blood	Not stated
	(2) Not stated	,,	Very bloody; sp. gr. 1,016; much sediment, mainly of epithelium and red and white blood cells	,,
	(3) ,,	,,	Bloody; sp. gr. 1,015; sediment as above	Bloody stool
	(4) ,,	,,	Bloody; sp. gr. 1,007; sediment as above	,,
XIII.	(1) Not stated	Not stated	Bloody; acid; albuminous; red corpuscles	Not stated
	(2) ,,	,,	,,	,,
	(3) ,,	,,	,,	,,
	(4) ,,	,,	,,	,,
XIV.	Not stated	Not stated	Bloody; hæmoglobin; no red discs	Not stated
XV.	(1) Not stated	Not stated	Bloody	Not stated
	(2) ,,	,,	,,	,,
	(3) ,,	,,	,,	,,
	(4) ,,	,,	,,	,,
	(5) ,,	,,	,,	,,
XVI.	Enumeration of red discs = 885,000 to 920,000 per cubic millimetre; hæmoglobin-value, 57 per cent; considerable diminution of red corpuscles; remnants of "broken-down" discs	Not stated	Bloody; no red corpuscles; oxy- and met-hæmoglobin	Thin brownish-red stools; diarrhœa

XVII.	Enumeration = 2,920,000 per cubic mm. ; hæmoglobin - value = 62 per cent ; little tendency to form rouleaux ; a few broken-down discs and "shadows"	Oxy-hæmoglobin	Bloody ; contained hæmoglobin ; free from biliary matters ; showed yellowish-brown casts ; no red discs	Normal stool
XX.	(1) Corpuscles mulberry - shaped and crenated ; some smaller and paler than normal ; some shadows; granular matter	Not stated	Bloody ; weakly acid ; numerous red and white corpuscles, and fatty and blood casts	Copious, then greenish-coloured stools
	(2) Not stated	,,	Bloody	Green-coloured stool
	(3) ,,	,,	Bloody; alkaline ; sp.gr.1,021; showed broken-down red discs, large yellowish-coloured epithelial cells ; coffin-shaped crystals	Not stated
	(4) ,,	,,	Similar, but not so marked	,,
	(5) ,,	,,	,,	,,
XXI.	Many shadow discs ; a few white corpuscles ; much disintegrated product	Not stated	Bloody ; hæmoglobin ; shadow discs ; epithelial casts ; large cells	Not stated
XXII.	(1) Not stated	Reduced hæmoglobin	Bloody ; spectrum of met-hæmoglobin	Hæmorrhages
	(2) ,,	Not stated	Bloody	,,
XXIII.	Not stated	Not stated	Bloody ; scanty ; hæmoglobin	Not stated
XXIV.	Not stated	Not stated	Bloody ; sp. gr. 1,032 ; plentiful sediment ; granules, but no red corpuscles or tube-casts	Not stated
XXVII.	A few broken-down red discs ; no rouleaux ; want of definition of edges of corpuscles generally	Not stated	Bloody ; broken-down red discs ; spectrum of hæmoglobin	Dark slate - coloured stools
XXVIII.	Enumeration = 1,800,000 per cub. mm. ; progressive anæmia	Not stated	Not stated	Not stated

TABLE IV.—*Continued*

Number of Observation.	Condition of Blood-Corpuscles.	Blood Spectrum.	Condition of Urine.	Condition of Bowels.
XXIX.	Discs, crenated or serrated	Oxy- and met-hæmoglobin	Bloody	Not stated
XXX.	(1) Not stated	Not stated	Bloody ; albuminous	Not stated
	(2) ,,	,,	,,	,,
	(3) ,,	,,	,,	,,
XXXI.	(1) Not stated	Not stated	Bloody	Not stated
	(2) ,,	,,	,,	Diarrhœa, with blood clots
	(3) Enumeration = 1,800,000 per cub. mm.	,,	Very bloody ; sp. gr. 1,022 ; alkaline ; albumin, 0·66 % ; urea, 1·4 % ; bile-pigment, but no bile-acids ; epithelial cells, epithelial casts, large exudation cells, a few red discs, and granular fatty matter ; no inorganic deposit ; spectrum of oxy-hæmoglobin, and, later, of met-hæmoglobin	Not stated
	(4) Enumeration = 2,700,000 per cub. mm.	,,	Bloody ; acid ; sp. gr. 1,025 ; bile-pigment ; no bile-acids ; albumin, 0·11 % ; urea, 2·7 % ; amorphous urates ; débris of red discs, epithelium large and small fatty and hyaline casts in large numbers ; spectrum of acid hæmatin ; later, of met-hæmoglobin	,,
	(5) Not stated	,,	Bloody	,,
XXXII.	Not stated	Not stated	Polyuria ; hæmoglobin ; albumin ; urobilin	Not stated

XXXIII.	(1) Not stated ; profound anæmia	Not stated	Bloody ; hæmoglobin	Severe diarrhœa ; stools at first loose, then rice-watery, then bloody
	(2) ,, ,,	,,	,,	,,
	(3) ,, ,,	,,	,,	,,
	(4) ,, ,,	,,	,,	,,
	(5) ,, ,,	,,	,,	,,
	(6) ,, ,,	,,	,,	Not so severe
	(7) ,, ,,	,,	,,	,,
	(8) ,, ,,	,,	,,	,,
	(9) ,, ,,	,,	,,	,,
	(10) ,, ,,	,,	Absent	Absent
XXXIV.	(1) Not stated	Not stated	Very bloody	Diarrhœa
	(2) ,,	,,	,,	Diarrhœic stools
	(3) ,,	,,	Very bloody ; neutral ; albuminous ; large number of casts ; decolorised red discs ; shadow discs ; some polynuclear leucocytes ; amorphous matter	Diarrhœic stools ; reddish coloured
XXXV.	(1) Not stated	Not stated	Bloody ; black like coffee ; scanty	Not stated
	(2) ,,	,,	,,	,,
XXXVI.	Not stated	Not stated	Bloody ; oliguria	Diarrhœa
XLI.	(1) Not stated. Corpuscles found broken down at post-mortem	Not stated	Bloody, like Condy's fluid ; showed a few broken-down corpuscles, tube-casts, and amorphous matter. No red discs or hæmoglobin	Constipation
	(2) Not stated	,,		Not known

TABLE V.

SHOWING (1) SOURCE OF THE GAS, (2) SOURCE OF THE ARSENIC, (3) RESULTS OF ANALYSES OF MATERIALS USED, AND (4) RESULTS OF ANALYSES OF ORGANS OF THE BODY OR OF EXCRETIONS.

Number of Observation.	Source of the Gas.	Source of the Arsenic.	Analysis of Materials for Arsenic.	Analysis of Organs, etc., of Patient.
I.	Interaction of As_2O_3 and KHO	Arsenious Acid	Not made	Not made
II.	Evolution of AsH_3 gas	Arsenical materials Reckoned to have inhaled gas equal to not more than $\frac{1}{3}$ gr. of metallic As.	Not stated	Not stated
III.	Arseniferous Hydrogen from Zn and H_2SO_4 and Arsenic	Chemicals used "But a very small portion of gas could have entered his lungs."	Not stated	Not stated
IV.	Arseniferous Hydrogen from Zn and H_2SO_4. Inhalation for Tyndall's experiment on the voice	In Zinc and Acid	Of Acid Six grains of Arsen. Sulphide got by treating 200 grains of acid with H_2S	In fluid both from pleural cavities. Believed that amount of AsH_3 inhaled equal to about 12 grains of As_2O_3
V.	Same as in III. Class demonstration	Chemicals used	Not made	Found in urine. Minute traces
VI.	Same as in IV.	Chemicals used	Zinc and Acid	Not made
VII.	Researches in Anilin colours	Not stated	Not stated	Not made
VIII.	Analysis of organs of person poisoned by Arsenic, by Marsh's process	Arsenic in tissues	Analysed in organs	Not made
IX.	Mistaken use of Arsenic Acid for H_2SO_4 with Zinc in generation of Hydrogen	Arsenic Acid	Proved by discovery of mistake	Not made
X.	Same as in IV.	Zn and H_2SO_4	Zn and H_2SO_4	Not made
XI.	Extraction of Silver from Lead ores with HCl	All the materials used	Materials, including acid, found to contain 0·027 per cent of Arsenic	Arsenic found in organs of the two deceased men
XII.	Filling toy-balloons with Hydrogen	Zn and H_2SO_4	Zn and H_2SO_4	Found in blood, bile, brain, and urine of the man of the series who died

XIII.	Same as in IV.	H_2SO_4	Acid contained much Arsenic	Not made
XIV	Work in Anilin manufactory	Zn and HCl	Zn and HCl	Found in liver
XV.	Manufacture of Zinc Chloride	HCl	HCl contained Arsenic	Not made
XVI.	Same as in XV.	Not stated	Not stated	Not stated
XVII.	Making Congo-red from Tin-dust Toluidin and HCl	Tin and HCl	Arsenic present in Tin and Acid	Not made
XVIII.	Not stated	Not stated	Not stated	Arsenic found in stomach and liver
XIX.	Living in rooms papered with arseniferous wall-paper	Wall-papers	Found in pigments of wall-papers	Not made
XX.	Same as in XII.	Zinc and H_2SO_4	In acid	Not made
XXI.	Same as in IV.	Zinc and H_2SO_4	Both contained As. markedly	Not made
XXII.	Utilisation of Galvanisers' Zinc-Skimmings	Materials worked with	Found in material as traces	In liver and kidneys
XXIII.	Reduction of Nitro-methyl-anilin with Zinc powder and HCl (alcoholic)	Zinc	Zinc contained As.	Not made
XXIV.	Filling captive balloon with Hydrogen	Iron filings and H_2SO_4	Acid contained 0·11 per cent	Not stated
XXV.	Dissolving mixture of metals with HCl	Metal mixture	Contained 0·8 per cent with traces of Antimony	Not stated
XXVII.	Same as in XV.	Zn and HCl	Acid contained Arsenic "freely"; the Zinc, traces	As. found in urine
XXIX.	Chemical operation involving use of HCl, in Anilin factory	Materials used	Found in Acid	Not stated
XXX.	Making AsH_3 gas	H_2SO_4	Acid, though sold as pure, contained Arsenic	Not made
XXXI.	Same as in XV.	Zn and HCl	Acid contained 0·40 per cent; Zinc contained traces	(1) In liver, kidneys, bile, urine, and blood, as well as in fluids from pleurae and pericardium In entire liver = 0·002 gram As_2O_3 (2) In liver, kidneys, and spleen In entire liver = 0·0016 gram As_2O_3

TABLE V.—*Continued.*

Number of Observation.	Source of the Gas.	Source of the Arsenic.	Analysis of Materials for Arsenic.	Analysis of Organs, etc., of Patient.
XXXII.	Dipping a Copper and Zinc plate into H_2SO_4, HCl, and As_2O_3	Arsenious Acid	Not analysed	In urine
XXXIII.	Same as in XV.	Zn and HCl	Acid contained 0·1 per cent; the Zinc, traces	Not stated
XXXIV.	Balloon gas	Acid = H_2SO_4	Acid	In urine
XXXVI.	Balloon gas	Iron and H_2SO_4	In both iron and acid	Found in stomach, heart, kidneys, and blood
XXXVII.	Balloon gas	Iron and H_2SO_4	Hydrogen gas contained As.	Not examined
XL.	Same as XII.	Zinc and Sulphuric Acid	H_2SO_4 contained 0·6 per cent	Not stated
XLI.	Removal of débris from a Welldon's Chlorine still with iron shovel and galvanised iron pail	HCl and débris in still	HCl contained as Arsenious Acid, 0·292 per cent; débris contained as Arsenic Acid, 0·45 per cent	In urine of deceased man
XLII.	"Pickling" in galvanising work	HCl	Acid contained 0·035 per cent	Not tested
XLIII.	Brazing a pipe with Hydrogen blow-pipe	Acid used	Acid was strongly arsenical	Not stated
XLIV.	Manufacture of Zinc Sulphate	H_2SO_4 (crude)	Not stated	Not stated
XLV.	Galvanic process for recovery of Copper in H_2SO_4 solution	Copper Sulphate	Proved that $CuSO_4$ gave off AsH_3 gas	Not stated
XLVI.	Recovery of Gold from Bismuth residuum (Bismuth Chloride) with Zinc powder	Bismuth Chloride	Bismuth contained nearly 2 per cent Arsenic Chloride	Not stated
XLVII.	Emptying tank of commercial H_2SO_4 residue with iron shovel and galvanised iron pail	H_2SO_4	Acid known to contain Arsenic	Not stated

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